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DEPARTMENT OF AGRICULTURE

THE EFFECT OF VARIOUS FACTORS ON THE DEVELOPMENT OF SWEDE SEEDLINGS AND THE SUBSEQUENT EFFECT ON CROP YIELD.

by

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Thesis submitted for the degree of
Doctor of Philosophy

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I. INTRODUCTION

Since the beginning of the present century, the acreage under turnips and swedes has shown (except during the war period) a steady decline, both in England and Wales and in Scotland. This reduction in acreage has largely been due to the high labour costs involved in growing the crop, and if the turnip crop (turnips and swedes) is to continue to play an important part in stock feeding, costs of production must be brought down, by increasing yields and by cutting labour costs through mechanisation.

Hunt (1953) estimated the cost of production of the swede crop as £58 per acre. Miller (1958) using Hunt's figures but making allowances for more modern techniques, put the cost of production at just below £50. At this rate, a 17 ton crop (the Scottish national average) costs £2:18s. per ton, while a 40 ton crop costs £1:4s. per ton. Although no allowance has been made for the greater costs of the larger crop, for example, in carting, these figures illustrate the importance of yield per acre in the economics of crop growing.

The need for yield improvement in British turnip crops was noted by Bain (1956) who compared prize-winning New Zealand crops of 80 - 90 tons per acre to the best crops in Scotland of around 50 tons per acre. It is interesting to study the estimated national yields of turnips and swedes in the annual returns of the Ministry of Agriculture and the Department of Agriculture for Scotland.

Table /

Table I shows the estimated yield of turnips and swedes in Scotland, and in England and Wales, averaged over 10-year periods from 1900.

Table I. The estimated yield of turnips and swedes in the United Kingdom, 1900 to 1959.

	10-year average	
	Scotland tons per acre	England and Wales tons per acre
1900 - 1909	16.1	13.5
1910 - 1919	16.3	12.5
1920 - 1929	17.1	12.5
1930 - 1939	15.7	11.3
1940 - 1949	17.2	12.5
1950 - 1959	17.8	15.6

The estimated yields are obtained from visual estimates made by crop recorders, and not by sampling and weighing. The figures seem very low, but there is some evidence of an increase in the average yields in England and Wales during the past 10 years. Any increase in Scotland since the beginning of the century, is small.

Yields can be increased in two ways: (a) through breeding, and (b) by improved husbandry.

Many plant breeders believe that little or no increase in yield in the swede crop can be obtained directly by breeding for new strains /

strains, though future improvements might be obtained indirectly through disease resistance, conformation, or through the breeding of hybrids. (Davey (1953), Davey (1960), Bogh (1960), and Horberg (1960).) Since breeding does not offer much hope of immediate yield improvement, the obvious course is to investigate the possibility of increasing yield by better growing methods.

Excluding the recent developments in mechanisation, turnip growing practice in Scotland has changed little in the last hundred years. Field operations have been largely a matter of custom and there is little evidence to show that these traditional practices have a sound scientific basis, for, in crop husbandry investigations, the turnip crop has received comparatively little attention.

Mechanisation of the various processes associated with growing root crops has proceeded steadily in the past few years. The precision seeder, mechanical thinner, and mechanical harvester, are becoming more popular, and give reason to hope that the turnip crop may become a more economic proposition. New methods, however, invariably bring with them new problems, and several factors associated with the mechanisation of the turnip crop, require further study.

II. HISTORICAL REVIEW.

The 17th Century saw considerable progress in British agriculture, and probably the greatest agricultural event of the century, was the introduction and development of the turnip crop. In the 16th Century in England, the turnip was regarded only as a garden vegetable, but on the continent towards the end of the century, improved methods of farming, involving rotations and the use of turnips,met with much success. Lord Charles Townsend (1674 - 1738) drew the attention of farmers to these continental innovations, and demonstrated their value on his own estate in Norfolk. By the early part of the 19th Century, the turnip was widely regarded as being essential to any system of cropping.

Meantime, the swede had appeared on the scene. Riddet (1925) says of the swede: "The spread of this plant had its beginnings in a packet of seed sent from Gothenburg in Sweden in 1777, and on account of its better feeding and keeping qualities, soon rivalled its sister crop in extent of cultivation. For many years the swede was grown with a certain degree of scepticism on account of its firmer texture and its requiring to be sown earlier in the year, which necessarily reduced the cleaning period of the ground. However, these objections were gradually waived aside, and now we have the swede and common turnip replacing each other and spoken of as 'the turnip crop', each used in accordance with the demands of the /

the soil and climate, and with the purpose for which grown".

At first, turnip seed was sown broadcast, but weeds proved to be a serious problem. This was soon overcome by the drill husbandry of Jethro Tull, which enabled horse-hoeing between the rows. Drills at first were as far as 6 feet apart, but this was gradually reduced to the present day widths. Riddet (1925) also noted that "by the middle of the 19th Century, the advantages of sowing seed on raised ridges in the wetter districts of the country were observed". This became practice in the northern parts of the country while in the drier regions in the south, turnips remained on the flat.

The introduction of the turnip crop brought great benefits to the farmer. He could now utilise his fallow land, and introduce some sort of rotation; he could retain a much larger head of stock over the winter months which not only provided fresh meat all year round, but left a greater supply of manure, and assisted developments in animal breeding.

The value of the swede crop as a stock food, lies in its ability to produce a high yield of succulent material which stores well over the winter months, and which can be fed to almost any class of stock.

Acreage Trends.

Increasing labour costs over the years have brought about a gradual reduction in the turnip crop acreage. Between 1900 and 1958 /

1958, the acreage of turnips and swedes in Scotland fell by 45%, while in England and Wales it fell by 81%. Table 2 shows the Scottish acreage of turnips and swedes in relation to the total arable acreage and to the total acreage of green crops excluding potatoes, from 1920 to 1958. In Table 3 similar statistics for England and Wales are given. The term 'green crop' is used to include turnips, swedes, mangolds, sugar beet, kale, rape, and cabbage.

Table 2. The acreage of turnips and swedes in Scotland in relation to the total arable area, and total acreage of green crops excluding potatoes, 1920 - 1958.

Year	Turnips and Swedes	Arable acreage	Turnips and Swedes as a percentage of arable land	Turnips and Swedes as a percentage of green crop except potatoes
	'000 acres	'000 acres	per cent.	per cent.
1920	425	3,380	12.58	95.5
1925	395	3,298	12.00	92.8
1930	372	3,072	12.13	95.3
1935	350	2,983	11.75	93.1
1940	303	3,063	9.90	86.8
1945	326	3,370	9.78	81.5
1950	287	3,210	8.95	82.3
1955	271	3,148	8.60	80.8
1958	256	3,145	8.10	78.1

Table 3. The acreage of turnips and swedes in England and Wales in relation to the total arable area, and total acreage of green crops excluding potatoes, 1920 - 1958.

Year	Turnips and Swedes.	Arable acreage	Turnips and Swedes as a percentage of arable land.	Turnips and Swedes as a percentage of green crop except potatoes.
	'000 acres	'000 acres	per cent.	per cent.
1920	991	12,020	8.2	63.9
1925	806	10,682	7.5	57.5
1930	671	9,832	6.8	46.6
1935	498	9,398	5.3	37.2
1940	433	10,139	4.3	37.3
1945	466	14,523	3.2	30.7
1950	300	13,949	2.1	22.2
1955	288	13,423	2.1	21.8
1958	246	13,489	1.8	19.4

In both Scotland, and England and Wales, part of the turnip and swede acreage has been replaced by other crops, as farmers have turned to forms of winter keep requiring less labour.

The acreage of green crops, other than turnips and swedes, has risen in Scotland by over 250%, from 20,173 acres in 1920 to 71,565 acres in 1958; and in England and Wales, by 83%, from 559,264 acres to 1,023,222 acres. In Scotland the acreage of cabbage and kale has risen from 3,498 acres to 17,572 acres between /

between 1920 and 1958. Many crops of kale have been grown by precision seeding without singling, and utilized by strip-grazing or forage-harvesting. The sugar beet factory was opened in Fife in 1926, and by 1958, nearly 16,000 acres of sugar beet were grown in Scotland. This crop has the advantage of being a cash crop, yet supplying winter keep in the form of tops and beet pulp.

Grass in the form of silage has also replaced turnips and swedes. Since 1951, the acreage of grass in Scotland cut for silage, has risen from 36,888 acres to 78,633 acres in 1958. The corresponding figures are not available for England and Wales, but in 1951, 1,632,000 tons of silage were made (arable and grass), while in 1958, 3,862,000 tons were produced.

The relative merits of feeding turnips and silage have been much discussed in recent years, and several experiments have compared the feeding value of the two foods for various classes of stock (Dodsworth 1951, Dodsworth 1953, Dempster 1953, Anon 1958, Hendrie 1958, Millar 1958, Bain et al 1960, Livingston 1960).

III. REVIEW OF LITERATURE.

1. The Effect of Seed Size on Germination, Emergence, Seedling Growth, and Crop Yield.

The influence of seed quality as reflected by the size of the seed, is a question of considerable importance to the farmer, and the effect of seed size on crop yield has provided a subject for much experimentation. There has been some renewed interest in the question in recent years with the introduction of the precision seeder with its inherent need for graded seed.

Results of the very large number of experiments which have been carried out to compare the performance of seeds of different sizes, are somewhat contradictory. One should bear in mind the number of factors involved and the different methods used by the numerous investigators.

Brenchley (1923) suggested that different sizes of seed could be compared, by sowing on similar areas

(I) equal quantities by weight

(2) equal quantities by volume

(3) equal numbers of seed - when comparison becomes a true one as regards the productivity of individual plants.

In considering the results of many large scale experiments, Kidd and West (1918) pointed out the difficulty that "we cannot definitely decide how far they (the results) are due, not to differences /

differences in vigour and yield of individual plants, but to differences in plant numbers. Germination also introduces an element of error from this point of view".

Closely related to the question of equal plant numbers is that of plant density. Black (1957) noted that "the importance of density of plant numbers does not always seem to have been taken into consideration in experiments on the influence of seed size on crop production; in most cases plants have been sown at the seed rate normal to local agricultural practice, or at equal plant numbers".

In their review of literature, in which a wide variety of crops was considered, Kidd and West (1918) stated that the balance of evidence was in favour of the conclusion that more vigorous plants and better yields were obtained by the use of heavy seed.

As far as most annual crops are concerned - certainly cereals, peas, and beans - there is a considerable amount of agreement on this point. In America, working with wheat, Georgeson et al (1893) obtained a considerable advantage with large seed. Similar results were obtained by Bolley (1901), Boss (1893) working with wheat and oats, and Soule and Vanatter (1901) with barley. In Britain, Findlay (1919) claimed yield advantages for large seed after experiments with oats, and Brenchley (1923) came to similar conclusions working with peas and barley. Lehmann (1869) also obtained yield advantages with large peas. Many more references to work on cereals /

cereals can be found in Cummings (1914), Kidd and West (1918), Brenchley (1923), and West (1930). The results are almost unanimously in favour of using large seed. The performance of annual plants however, particularly cereals which have endospermous seed, is unlikely to be applicable to swedes.

Results obtained with rape and radish, which although annual crops, have seed similar to the swede (being exendosperous and epigeal) are also in favour of large seed. Rotunno (1924) and Cummings (1914) working with rape, found that large seed had a decidedly higher germination percentage than small seed, and Cummings (1914) found that large seed outyielded the small by 120%. Cummings' 'germination' figures,however,refer in fact to emergence; not laboratory germination. Cummings also found that the dry matter percentage of bulbs grown from small seed was higher than that from large seed. Unfortunately, much of Cummings' work was confused by differences in plant numbers. Working with rape, Sirks (1926) concluded that the larger the seed, the larger was the plant from it, and that the plants grown from the larger seed flowered earliest.

Opinion is more divided in the case of biennial and perennial crops, or plants with a long growing period. The weight of opinion is agreed that large seed of crops in this category have an advantage over small in the early stages of growth. The main point of contention is whether or not this advantage persists.

Kotowski (1925) noting that most of the work done up to that time /

time had been done on annual crops, carried out an experiment with cabbage. Four replications of a 2^2 factorial were laid down, the treatments being two sizes of seed sown on fertilised and unfertilised plots. He concluded that, in the development process, the seedling was dependent to a large extent on nutrients from the soil, that seed size influenced production up to the sixty day stage, but that with further growth the advantage obtained from the large seed disappeared.

Schmidt (1921) compared three grades (by weight) of crimson clover seed, planting equal numbers of seed. The lighter seed germinated later than the heavy, and out of fifteen seeds of each weight, eight light seeds germinated and thirteen heavy seeds. Plants were harvested at four dates and from their dry weights, Schmidt concluded that during the early stages of growth at least, the advantage was with the heavier seed.

Black (1956) obtained similar results with subterranean clover. He firstly gave consideration to depth of sowing and found that seed size determined the depth from which emergence could take place, but there was no evidence of an interaction between seed size and depth of sowing either for seedling weight or growth rate. He found that the area of the cotyledons determined the extent of the difference in the early vegetative growth between plants from different seed sizes, this applying only to plants having epigeal germination and endospermous seed. The plants were harvested at three /

three dates and it was found that the effect of seed size on plant weight was positive and significant at the 0.1% level; and that in the absence of an interaction between seed size and sampling occasion, the relative growth rate of plants grown from different seed sizes, was identical, the absolute growth of the plant depending on the size of the embryo. Black expressed this result in terms of the Compound Interest Law which Blackman (1919) applied to plant growth: plant weight at any one time depends on 'initial capital' since 'rate of interest' is the same. Black (1957) went on to see if the early advantage inherent in large seed persisted until maturity. He considered the effect of seed size on plant growth under spaced and sward conditions. He found that, in the former case, the dry weight of the plants remained proportional to the seed weight from the time of sowing till the end of October. On the other hand when grown in a sward, the dry weight of the plants was proportional to seed weight only in the first part of the season. As plant competition became effective, i.e. when the swards reached a leaf area index of about 4 (4 square links of leaf to 1 square link of ground) growth rate was slowed down, firstly for the large seed and then finally for the small seed, so that at the final sampling in the autumn there was no significant difference between the dry weights of the plants from different seed sizes.

Oexemann (1942) working in the green house with soya bean and cucumber, which like the swede are epigeal and endospermous, determined /

determined the relationship between seed weight and weekly increase in stem elongation. In general, the highest correlation values were found in the second, third and fourth weeks. In the sixth and seventh week, values showed a marked decrease, and then became negative. Unfortunately, Oexemann did not state the distance between the plants, and it is unknown therefore, if competition for light occurred. However, this relationship between seed weight and growth rate in the early stages of growth supports the results of Gould (1934). Gould, working with the canteloup seedling (Cucumis melo) under carefully controlled conditions, found that the metabolic translocations of reserve food material from the cotyledons to the growing point was more efficient in the seedling containing the smaller amount of stored food. Oexemann (1942) concluded that the early superiority of the plants from heavier seeds over that of plants from lighter seeds, gradually disappeared and that if the growing season was long enough, the earlier differences could disappear altogether. This agrees with Golinska's (1929) results which showed that the length of growing period and speed of development of plants is hereditary and cannot be influenced much by seed weight.

The first work with the swede appears to have been done by Zavitz (1907) who also included mangolds, sugar beet and carrots in his experiments. Two series of experiments were carried out; one in which equal numbers of seed were planted separately, and one /

one in which equal numbers of plants were left when singling. All crops showed similar results, and Table 4 gives the results obtained with swedes.

Table 4. The yield obtained from three sizes of swede seed (Zavitz 1907).

	Number of years of test	Yield (tons per acre)		
		Large seed	Medium seed	Small seed
Equal number of seed sown.	5	15.35	12.63	7.03
Equal number of plants left when thinning	5	18.77	17.85	10.40

The large seed yielded approximately twice that of the small seed.

Findlay (1919) considered the question from two points of view:

(i) Different sized seeds in the same sample. Two sizes of seed were compared, but Findlay gives no indication of actual seed size or weight. At brairding, differences were marked, but as the season advanced, the differences grew less, though the plants from the large seed always looked better. The roots were weighed in early winter, and the large seed of the four varieties tested gave on average, 19 tons, 9 cwt. per acre, and the small seed 17 tons, 3 cwt. per acre.

(ii) Different sized seeds of different samples. The different /

different samples were the produce of different bulbs which were found to produce seed of widely differing sizes. Large seed was again found to have an advantage over small, but considering all strains, the weight of the crop "bore no relation to the seed size". Findlay concluded that strain was more important than seed size. In another experiment in which 100 large seeds and 100 small seeds were weighed, and 100 plants from each seed size weighed at intervals during the season, Findlay found that the plants from the large seed were always superior but that their relative superiority to plants from small seed gradually decreased. Three weeks after sowing, the plants from the small seed weighed 48% of those from the large seed; 5 months after sowing, plants from the small seed weighed 89% of those from the large seed.

In America, Leggatt and Ingalls (1949) compared five sizes of swede seed. In laboratory germination tests, there was no difference in germination percentage or speed of germination between the seed sizes. Hypocotyl lengths were measured and showed no difference. At harvest, the mean weight and volume of the roots did not differ significantly in two years of trial. Leggatt and Ingalls also investigated the relationship between size of seed and shape of root, and found that there was a definite tendency for the two smallest seed groups to produce flatter roots.

As far as the effect of disease on plants from different seed sizes is concerned, Findlay (1931) suggested that plants from large seed /

seed by reason of getting a better start than plants from small seed, are more resistant to disease. In support of this, Oexemann (1942) stated that "a higher mortality rate was found among seedlings grown from seeds of lighter weight than among seedlings grown from heavier seeds. This difference in mortality rate is probably due to differences in plant vigour and disease susceptibility".

Considering the results of the various workers, it is generally agreed that small seeds produce smaller plants in the early stages of growth than large seeds, but that the early superiority of the plants from the large seeds gradually diminishes. The extent to which final yield is affected, appears to be dependent on the crop, and on the length of the growing period. With swedes, the balance of the evidence is in favour of the view that some yield advantage follows the use of large seed.

2. The Effect of Soluble Fertiliser Salts on Germination and Seedling Growth.

Lawes (1847) found that superphosphate mixed with turnip seed and sown in an ordinary drill was more efficient than the same material mixed with the cultivated layers of the soil. Nitrogen fertiliser used in this way damaged plant establishment severely in the dry seasons. Since that time, a considerable amount of investigation has been made into the various methods of fertiliser application and the amounts of fertilisers which can be applied to give maximum development compatible with high yields, without adversely affecting germination.

In the literature there appears to be some confusion of the terms 'germination' and 'emergence'. In this text, 'emergence' is used to indicate the emergence of plants from the soil, while the term 'germination' refers to the appearance of the cotyledons from the testa - or laboratory germination.

(a) The effect on emergence.

Some of the earlier work with the turnip was carried out in New Zealand. Hudson (1928) drilling seed and fertiliser together on the flat, found that raw phosphates had no effect on emergence, but that 1 cwt. per acre of superphosphate reduced the emergence percentage to between 65 and 75% of that expected when no fertiliser was applied; 2 cwt. per acre of sulphate of ammonia reduced the emergence to between 40 and 50% of that expected. With the same method /

method of drilling, Woodcock (1930) obtained similar reductions in emergence with superphosphate and with sulphate of ammonia. In a higher rainfall area, where swedes were sown in 26-inch ridges, Tennent (1931) studied the effects of sowing superphosphate alone, and superphosphate with lime, on swede and turnip seed. The fertiliser was applied with the seed and under the seed. Results showed conclusively, for that season, that superphosphate at rates of 1- 1½ cwt. per acre sown with the seed, gave a considerably reduced emergence and lower yield than when the same quantity of superphosphate with lime was sown with the seed. In a series of some 48 experiments over a period of seven years, in which turnip seed and fertiliser were sown together on the flat, Hudson and Woodcock (1932) found that the advantages of applying superphosphate were only obtained when the effects of the fertiliser on emergence were eliminated or reduced by the addition of lime. One cwt. of superphosphate per acre reduced emergence by 42% of that obtained with 1 cwt. of superphosphate plus 1 cwt. of lime per acre, and the yield was reduced by 3.4 tons per acre; 2 cwt. superphosphate reduced the emergence by 52% of that obtained with 2 cwt. superphosphate plus 2 cwt. of lime, and the yield by 4.6 tons per acre. Lewis (1941) carried out experiments with swedes at four centres in Wiltshire and Dorset to compare broadcasting and drilling fertilisers on the flat. The fertilisers were: 1 cwt. of sulphate of ammonia per acre; 5 cwt. of superphosphate per acre; 1 cwt. of potassium /

potassium salts per acre - sown together and alone. Superphosphate had no effect on emergence; potassium salts had no effect when broadcast but reduced stand and yield at three centres when sown in the drill; sulphate of ammonia had no harmful effects at any of the centres. Lewis concluded that sowing in bands at the side of the seed was the most satisfactory method of placement; that sowing below the seed gave good results only on deficient soils and that sowing in contact with the seed entailed serious risk of impaired germination. Lewis also carried out a brairding test which confirmed that superphosphate may cause harm when sown in the drills. No details are given of the method of fertiliser application or the way in which the seed was sown.

Table /

Table 5. Swedes - percentage emergence (Lewis, 1941).

Days after sowing	7	8	9	10	11	12	18	24
O	26	57	70	74	76	81	83	85
N	3	12	24	29	32	35	42	44
P	3	11	18	24	25	28	33	32
K	4	14	19	22	26	31	44	54
NP	1	6	12	15	17	17	19	21
NK	0	1	3	4	6	6	18	24
PK	1	8	11	12	12	12	15	18
NPK	1	4	6	11	12	12	15	18

N - 1 cwt. sulphate of ammonia per acre.

P - 5 cwt. superphosphate per acre.

K - 1 cwt. potassium salts per acre.

Cooke (1949) carried out an experiment on seven sites in 1947 to compare the effect of 4.5 and 9.0 cwt. per acre of National Compound Fertiliser No. 2 (9% N, 7.5% P_2O, 4.5% K_2O), broadcast, placed in various positions, and in contact with the seed. Contact placement at both rates of dressing, and placing below the seed at the high rate, gave a lower mean plant population than broadcasting, but placing in bands 1 inch and 3 inches to the side of the seed was safe. The average yield given by contact placement was similar to that given by broadcasting. Placing the fertiliser below the seed, increased /

increased the yield by 2.54 tons per acre, and placing 1 inch and 3 inches to the side of the seed, increased the yield by 2.09 tons per acre, and 1.41 tons per acre, respectively.

Reith (1959) growing swedes on the ridge, found that 40 lb. of nitrogen per acre as sulphate of ammonia, placed below the seed, reduced germination and gave lower populations; broadcasting the fertiliser before ridging, and placing to the side of the seed had no effect on germination. None of the placement methods increased the yield. Germination was unaffected by superphosphate at rates of 30-80 lb. P_2O_5 per acre, whatever the method of application, and the superiority in yield of placing superphosphate in narrow bands directly below the seed was clearly demonstrated. Indeed, the number of roots was sometimes increased by phosphate. Muriate of potash up to 120 lb. K_2O per acre, had no effect on germination and Reith concluded that there was "no advantage or great disadvantage in band placement" of potash. Reith (1954) obtained similar results with single nutrient fertilisers in an earlier series of experiments.

The effect of mixed fertilisers was also considered by Reith (1959) who found it inadvisable to place a mixture of sulphate of ammonia and muriate of potash (40 lb. N per acre plus 100 lb. K_2O per acre) directly below the seed. Placing 2 inches to the side was safe and similar in effect to broadcasting before ridging. In both series of experiments, Reith found no advantage from placing NPK mixtures. With band placement the damaging effect of sulphate of /

of ammonia and muriate of potash in the mixture counteracted the beneficial effect of the phosphate.

(b) The effect on the seedling.

Lewis (1941) stated that "it is widely assumed that if soluble fertilisers are drilled in contact with the seed of swedes, germination is impaired and many young seedlings killed". In many of the experiments reporting damage to germination, only a few noted also damage to the seedling, and little indication has been given of the extent of the injury. Scott Watson (1935) noted the "burning" effect on the seedling. In New Zealand, Hudson (1928) noted that the injury caused by excessive superphosphate persisted for some time after the plant came through the soil, when plants were yellow and stunted. Reith (1959) found that sulphate of ammonia at the rate of 40 lb. of nitrogen per acre, placed below the seed, not only reduced germination but retarded early growth. Contrary to this, Maxton (1927) working with grass and clover seed, concluded from a number of experiments conducted to study the effect of solutions of fertiliser salts of different concentrations on the germination of the seed and the plasmolysis of the seedling, that the concentration which allows seed to germinate will not materially injure the seedlings.

On the other hand, placement of fertiliser can assist the development of the young plant by placing nutrients, particularly phosphate, in such a position that the seedling can make best use of /

of them when its need is greatest. This influence of placed fertiliser is reflected in the increased yields obtained by Lewis (1941) and by Reith (1959). The latter noted that the stimulation to early growth under low phosphate conditions was greatest where phosphate was placed below the seed, and that this method of placement gave a higher yield than placing to the side of the seed, where the phosphate was not in the best position to be used by the young plant. Cooke (1949) in a year of low rainfall, obtained better results by placing fertiliser than by broadcasting: the benefits of the fertiliser on crop establishment and yield more than compensated for any damage done to the germination by placing the fertiliser.

(c) Factors influencing the effect of soluble fertiliser salts.

The practical evidence concerning the amount of fertiliser which can be safely applied, and the way in which it can be applied is conflicting. What may be successful in one area may be disastrous in another. It would appear that the effect of a fertiliser on emergence depends firstly, on whether or not the soil is deficient in the particular nutrient, and secondly, on the amount of moisture present in the soil.

(i) The availability of soil nutrients.

The general conclusion reached by workers is that where a soil is deficient in a particular nutrient, placement is beneficial; where /

where there is no deficiency, there is risk to emergence. The depression in emergence percentage obtained in New Zealand with superphosphate by Hudson (1928), Hudson and Woodcock (1932), and Tennent (1931) was obtained on phosphate-rich soils. The importance of the availability of soil nutrients in determining the amount of damage done to emergence by fertiliser was also noted by Miles (1930) and by Lewis (1941). The latter noted, on the one hand, the negative effect of phosphate on emergence, and yield increases obtained by placement of phosphate on deficient soils; and, on the other hand, the poor plant establishment and low yields on phosphate-rich soils. Hanley (1947) recommended great caution in combine drilling fertiliser with root seeds, and stated that "on soils very deficient in potash, special benefits may sometimes accrue, but in most circumstances, the result is likely to be harmful to germination and brairding". Reith (1959) noted that the effectiveness of placement depended on both responsiveness and type of soil; that the benefits of band placement were generally greatest on soils which gave large responses to, and which were deficient in phosphate, and on basic igneous soils rather than on soils of granite or old red sandstone origin.

(ii) The soil moisture content.

The importance of the soil moisture content as a factor affecting fertiliser damage to emergence, was noted by Shive (1916) in America. He reported that the retarded germination of beans and corn /

corn due to salts was directly related to the amount of water absorbed by the seed and was in turn dependent on the concentration of the soil solution. Ayers (1952) obtained similar results. The mechanism of this effect has been explained by Hudson (1928): the fertiliser is soluble in water, and heavy dressings placed in the soil produce a comparatively strong solution - resulting in plasmolysis. Parker and Oliver (1938) showed that fertiliser mixed with soil of low moisture content was more harmful to the germination of peas, beans, and cabbage than when placed two inches below the seed; fertilisers placed to the side and below the seed were relatively non-injurious irrespective of soil moisture content. Olsen and Drier (1956) working with wheat and oats, found that there were relatively small harmfull effects of fertiliser on germination, where fertiliser and seed were incubated with soil that was air-dry or of greater than 1/6 available moisture content; where the moisture content of the soil was low, and of excessive total stress (physical osmotic pressure) for germination, yet of sufficient magnitude to dissolve the fertiliser, the result was maximum damage to germination. This explains why loss in stand is sometimes greater in a soil of moderate moisture at sowing, than in one with very little moisture.

The importance of soil moisture for satisfactory emergence with placed fertiliser has been emphasised by Miles (1930) and by Reith (1951), and rainfall is made an important condition in the recommendations /

recommendations on placement made by Hanley (1947).

Lack of soil moisture can also explain in part the damage to germination by superphosphate in the low rainfall areas of New Zealand (Hudson - 1928, Hudson and Woodcock - 1932), and by sulphate of ammonia (Woodcock - 1930). The low rainfall in 1947 is the explanation given by Cooke (1947) for serious depletions in plant establishment, where the seed was sown in contact with the fertiliser, and where fertiliser was placed directly below the seed. Cooke stated that the extent of damage by fertiliser must depend on the amount and distribution of the rainfall from sowing until the plants are well established, on the texture of the soil, and on the moisture content of the soil at the time of sowing.

Soil moisture is not only important in limiting fertiliser damage but in rendering the soil nutrients available to the plant. Cooke (1947) noted that in the low rainfall of 1947, placement showed a marked superiority in yield to broadcasting, and suggested that the broadcast phosphate remained in the top soil and was useless to the phosphate-sensitive seedlings, whereas the phosphate, placed in bands, stimulated root growth. In this year, the marked benefits to crop establishment and yield more than compensated for any damage to germination caused by fertiliser placement below or beside the seed.

3. The Effect of Plant Population and Plant Distribution on the Yield and Quality of Roots.

(a) Spacing Distance.

It is obvious as not to require experimental proof, that close spacing restricts the growth of plants; it is equally obvious that excessive inter-plant spacing will reduce crop yield. The purpose of most population studies is to examine populations within a sensible range with a view to ascertaining optimum spacing distances.

The fundamental relationship existing between crop yield and plant population has received considerable attention. Holliday (1960) carried out population studies over a period of several years on a wide variety of crops and found that two quite distinct yield/ plant population relations existed, according to whether the yield in question was a product of the crops growth in the reproductive phase or a product of growth in the vegetative phase. In these experiments, a wide range of plant populations was studied to permit the yield obtained to be plotted graphically against the population.

The curve obtained with cereal grains for example, where yield is a function of reproductive growth, was a flat topped parabolic type of curve in which a point of inversion was reached, indicating that there was an optimum plant population which give rise to maximum yield. Many references in support of this are quoted by Holliday (1960).

The /

The curve associated with vegetative growth was an asymptotic type of curve which showed no point of inversion. Instead the yield increased at a diminishing rate with increasing plant population until the curve became parallel to the base axis of the graph. This relationship was obtained by Holliday (1960) in the case of dry matter yields in the rape crop, and similar results were obtained with both marrow-stemmed and thousand-headed kale (Roebuck, 1959) and with total yield of potato tubers (Saunt, 1960).

Further evidence of two kinds of curve, vegetative and reproductive, is supplied by Donald (1951) in Australia, working with Wimmera Ryegrass and Subterranean clover, Crowther (1935) in experiments with maize and cotton, and more recently Bunting and Willey (1959) with maize.

Holliday (1960) suggested that the yield/plant population curve, where yield is a product of growth in the vegetative phase, could be defined by the expression:

$$y = Ax. \frac{I}{I + Abx}$$

where y = yield of dry matter per unit area, A = the "apparent" maximum yield per plant, x = number of plants per unit area, and b = the linear regression coefficient of the reciprocal of yield per plant and plant population. In this expression the term I/(I + Abx) represents the manner in which the maximum plant yield (A) is reduced by the increasing competition resulting from greater plant density. In consequence, it may be termed the "competition function".

A /

A similar yield/plant population relationship has been obtained by other workers. Hunter-Smith and Rhys-Williams (1927) working with sugar beet, fodder beet, and mangolds showed that yield per acre increased asymptotically with an increase in plant population. Similar results with sugar beet were obtained by Engledow et al (1928).

Some interesting observations on the effect of close spacing of garden beet were made by Warne (1953) who noted "the almost, and sometimes quite complete dependence of root size on available space". He believed that the smallness of closely spaced plants could not be explained by competition for water, light, or the major nutrient elements, but that some unknown factor appeared to restrict their size.

There is some evidence in the literature to suggest that soil fertility affects the level at which the plant population becomes limiting to yield. In a series of Dutch experiments published by Boyle (1952) there was a clear indication that soils of low fertility required higher plant populations to reach full yield potential than did soils of high fertility. On the other hand, some Danish experments also reviewed by Boyle, failed to indicate a significant interaction between plant spacing and manurial treatment. This aspect of populations is considered further in the discussion of results.

Some of the earliest work with the swede crop was done at the Edinburgh College of Agriculture (Anon - 1906), and Table 6 shows the /

the effect of populations on the yield of roots.

Table 6. The effect of plant populations on the yield of roots, (Anon - 1906).

Number of roots roots/acre.	Yield of roots tons/acre.
27,376	18.2
20,176	17.8
15,415	17.4
12,860	16.1

No statistical technique was employed, but the results suggest a gradual loss of yield with decreasing populations.

Plant populations were also studied at the West of Scotland Agricultural College (Anon - 1929). Spacing distances of 8, 10, and 12 inches were compared, and the mean yields for two years of trial are shown in Table 7. In the second year of trial the swedes were grown at three row widths (24, 27 and 30 inches) and the average yield of the row widths is taken.

Table 7. The effect of plant spacing on the yield of roots, (Anon - 1929).

Plant Spacing inches.	Yield of roots tons/acre.
8	22.1
10	23.3
12	22.2

The plant spacings used, therefore, had little effect on the yield of roots.

Gilchrist (1919) mentioned that singling swedes 8 inches apart gave the highest yields. Unfortunately, no further information was given. More extensive trials were carried out by Whitehead (1935) who compared 8-, 11-, and 14- inch spacing, and found that the 8-inch spacing outyielded the 14-inch spacing significantly by 1.5 tons per acre in one year, while a similar tendency in the following year failed to reach significance. He noted that the size of individual roots was reduced parallel with a reduction in the spacing, but that although this reduction was a significant one, it was not sufficient to bring the total yield of widely spaced roots up to that from the 8-inch spacing.

(b) <u>Distribution.</u>

Closely related to spacing distance is the regularity of the spacing. This question of distribution has been investigated by Rayns (1951) who stated that mathematical accuracy in inter-plant spacing or singling intervals is unnecessary and that a swede plant in a population of other swedes in which there are no gaps, will grow just as large whether it is placed 14 or 15 inches from surrounding plants.

Working with sugar beet, Davis (1930) compared spacing distances between 4 and 10 inches and concluded that within this range, yield was not related to number of roots per acre, but was affected by distribution /

distribution. Garner and Sanders (1939) came to similar conclusions concerning spacing within the range 6 to 12 inches. In addition, they estimated the effect of gaps and calculated from the weight of a 'perfect' beet, that is, one which was completely surrounded by beet plants, the amount of compensation relating to a gap. They found that in a dry year, the roots immediately surrounding a gap, compensated to the extent of 80-89% for the missing plant. In a wet year, compensation was less complete, amounting to 41-84% under various spacing treatments. Brewbaker and Denning (1935) found that beet surrounding a gap compensated for it to the extent of 96% and that the "uniformity of space allotment, or, in other words, the elimination of skips or blank spaces in the stand, appeared to be relatively a far more important factor in determining final yields than the particular width between rows or the spacing between beets in the row."

Thomson (1956) carried out a series of experiments to determine the effect of irregular spacing on the yield of sugar beet sown in 20-inch rows. The experimental treatments consisted of four mean plant spacings in the row (9, 12, 15, and 18 inches) combined with four degrees of irregularity (U, A, B, and C). In general terms, the treatments represented plant distributions obtained from uniform spacing (U), 1/8 irregularity (A), 1/2 irregularity (B), and complete irregularity (C). These treatments represented the plant distributions to be expected from the following operations:

(U) /

(U) Uniform spacing.

(A) Normal hand-singling.

(B) Twice-through with a down-the-row thinner, followed by hand hoeing.

(C) Twice through with a down-the-row thinner with no subsequent hand work.

Table 8 shows the mean yield of clean beet obtained from 11 centres over a period of two years.

Table 8. Mean yield of clean beet in tons per acre (Thomson, 1956).

Spacing inches	Degree of irregularity U	A	B	C
9	13.3	13.8	13.2	12.5
12	13.7	13.5	12.8	12.6
15	13.3	12.9	12.4	12.1
18	12.7	12.7	12.5	11.5

Thomson concluded that, since hand singling at 15- inch mean spacing resulted in almost the same sugar yield (43.6 cwt. per acre) as complete machine thinning at 9- inch mean spacing (43.3 cwt. per acre) the adverse effects of irregular spacing may be completely offset by increasing the plant population. Thomson stated: "At equivalent plant populations, a comparison of the (A) and (B) treatments .... indicates that the loss in yield due to the more /

more irregular spacing is approximately 1/2 ton of clean beet per acre"; compared with (C) the loss was slightly less than 1 ton of clean beet per acre. Averaging the results of the two years, the difference in yield between uniform spacing and complete mechanical thinning, was 0.8 tons per acre at 9- inch mean spacing, and 1.1 tons at 18- inch mean spacing.

The effect of 'doubles' in sugar beet was investigated by Jones (1955). Stands containing up to 25% 'doubles' did not lower yields, but they did increase labour requirements when harvested by hand, and interfered with efficient machine harvesting. Jones considered that these results were equally applicable to swedes, and where harvested by hand these could be even more sparsely sown and thinned mechanically. More recently, Harvey (1957) showed that up to 20% doubles had no effect on yield but that above 50% doubles appreciably decreased yield.

(c) The effect of population on dry matter content.

The closer the spacing distance between plants, the smaller are the plants. This is a matter of some importance since the size of the swede bulb has been found to affect its dry matter percentage.

Berry (1925) found a wide variation in the dry matter percentage of individual roots of the same variety, and obtained variations in dry matter percentage from 7.8 - 15.6 in sampling 100 roots. As a rule, large roots had a low dry matter, and the smaller ones, a high dry matter content. Wood and Berry (1905) obtained similar results with /

with mangolds, Hendrick and Greig (1903 and 1904) stated "it is a well known fact that individual roots of the same species, grown on the same land side by side, vary considerably in composition. Generally speaking is is known that large bulbs are lower in dry matter than smaller ones, but both large and small bulbs vary much among themselves".

Collins (1905) weighed 100 large and 100 small roots, the large being between 5 and 6 lb. and the small between 2 and 3 lb. The dry matter percentage of the small bulbs was higher than that of the large bulbs by 0.94%.

Sansome (1926) studied the correlation between root size and dry matter percentage. He found a negative correlation between the weight of a core and its dry matter percentage. The correlation coefficient was -0.66 in the autumn, and -0.51 in the spring.

(d) Dry matter as an indication of feeding value.

Towards the end of the 19th century, an extensive series of experiments was conducted by the Marquis of Tweedsdale to improve the quality of the swede crop, by selecting as seed-mothers, turnips of the highest specific gravity. Anderson (1855) discovered however, that the specific gravity of the whole turnip was a very uncertain guide to quality, due to the variable quantity of air contained in the cells of different bulbs, though the specific gravity of the juice gave a very accurate estimate. Since that time, dry matter content has received more attention and a number of feeding trials have /

have been conducted to find if the dry matter percentage was related to the nutritional value.

Collins (1905) described a feeding trial in which sheep were fed rations exactly alike except that some sheep received one kind of swede and some another kind, the swedes as well as the other foods being subjected to chemical analysis. The results showed that there was a very direct relationship between the feeding value and the amount of dry matter in the swede. He was unable to trace any relationship between the feeding value of the roots and the amount of any other constituent in the root. He concluded that the chemical determination of the dry matter was the most satisfactory means of determining the relative feeding value of swedes. Collins stated that even a purely theoretical consideration would lead to the same conclusion, since the water in the swede can have no value in itself, and all the other constituents are so easily digested. He considered that no great error would result if the dry matter was considered to be wholly digestible.

Lauder (1927) carried out a large number of determinations of the various constituents of the swede "in the hope of getting some analytical figures, which might be related to the quality of the roots". The results obtained, varied in a most irregular manner, and Lauder stated that the large amount of work had produced little or no definite results, except to confirm the view that the percentage of dry matter, other things being equal, is the most useful figure to /

to determine. Lauder proceeded to carry out a feeding trial with sheep to compare the variety Kinaldie (dry matter percentage 12.06) and Picton (dry matter percentage 10.41). Equal weights of dry matter were fed, and the experiment showed no difference in the feeding value of the dry matter in the two varieties.

In considering the quality of individual roots, however, Hendrick (1906), in a search for seed-mothers of the highest feeding quality, believed that consideration of the dry matter was not enough. He found that the insoluble fibrous material which is much more difficult to digest, varied considerably in different bulbs, and that a more reliable indication of quality was the quantity of dry matter in relation to the ratio of soluble to insoluble material.

McCandlish (1931) in feeding trials with dairy cows to compare roots stored by different means - earthed-up, ploughed-in, unprotected, and pitted - found that pitted roots, although higher in dry matter content than the others, were lower in feeding value. He concluded that the condition of the crop as well as its dry matter content must be taken into account when determining its feeding value.

4. The Effect of Weeds.

With the high labour costs associated with modern farming, an urgent problem is to be able to control weeds cheaply. For the execution of any weed control programme, therefore, whether it be hand-weeding, mechanical hoeing, or the use of chemicals, it is of some value to know how many weeds can remain in the crop without affecting yield, and at what stage of crop plant development weed competition is most severe. The quantitative effect of weeds on agricultural or horticultural crops has been the subject of a number of investigations.

The real purpose of hoeing is to remove or minimise competition with weeds. Competition is defined by Bleasdale (1959) as follows: "Two plants are in competition with each other when the growth of either one or both of them is reduced, or their form is modified as compared with their growth or form in isolation".

Russell (1947) listed the sources of competition occurring between weeds and crops. He stated that weeds removed soil nutrients and water, and that if these were in short supply, crop growth was impaired; they shaded the crop plants, though a large number of tall weeds had to be present before competition for light was severe; the root systems of the weeds could interfere with those of the crop plant.

(a) The effect of weeds as influenced by the stage of crop development.

Bleasdale /

Bleasdale (1959), in two experiments with onions and one with red beet, showed that even when the crop was subsequently kept weed free, delaying the first weeding could significantly reduce the yield of marketable produce.

Bleasdale (1960) studied the effect of chickweed (Stellaria media) on carrots, and concluded that reducing the number of weeds alleviated the competition encountered by the crop far less than delaying the introduction of weeds. Considering a number of experiments with carrots and red beet, Bleasdale concluded that the first few weeks of a crop's growth was the critical period of weed influence.

Working with carrots and red beet, Shadbolt and Holm (1956) removed weeds at three stages of crop plant development, that is, 3½, 4½, 5½ weeks after emergence of the crop plants. The weight and size of the crop plants were measured at two period - (i) when the weeds were removed, early in the season, and (ii) in the autumn, after the crop plants had matured. With carrots, the results indicated that most of the injury occurred by 4 1/2 weeks after emergence. An additional week increased the degree of injury only slightly. Although the carrots recovered somewhat after the removal of the weeds, the presence of weeds for 4 1/2 weeks or longer after emergence reduced the fresh weight of roots and the total plant weight (measured in the autumn). This was significant at the 1% level of probability. With red beet, early measurements showed reductions /

reductions in plant weight compared with the weed-free control, of 40% even when weeds only remained for 4 weeks, but it was found that by maturity in the autumn, the beet plants made an almost complete recovery from the injurious effects of the weeds early in the season. Shadbolt and Holm associated this apparent tolerance to weed competition to the early production of large leaves in the beet, which shaded the weeds.

Russell (1947) stressed the importance of early hoeing. He stated that field experiments had shown in general that weeds were more harmful in the young crop than when it was well established. Weeds in the seed-bed could depress the germination of the crop or increase the mortality of the very young plants. Quite moderate weed infestations in the young crop could cause a very considerable decrease in yield. In experiments with sugar beet, Russell obtained increases of 2-3 tons per acre by doing a single additional hoeing in the young crop, when weed competition did not look very serious. Russell noted on the other hand, that weeds in established crops of sugar beet may look very bad yet have no effect on the crop yield. He suggested that similar results could be expected from the swede crop. In still other cases, Russell found that weeds could sometimes be relatively harmless to the crop even in the fairly early stages of growth, if the soil were sufficiently fertile.

(b) The influence of fertility on competition.

Russell et al (1942) studied the effect of inter-row cultivation

of /

of sugar beet, on the sandy loam soil at Woburn, and on the heavy clay-with-flints soil at Rothamsted. At Woburn, he concluded that if soil nutrients were in short supply, hoeing or hand weeding would increase the yield provided these operations were carried out before or shortly after singling; if soil nutrients were present in adequate amounts, inter-row cultivation would have little effect on yield and the crop could tolerate a considerable weed infestation without any effect on yield. At Rothamsted, he found that additional hoeings after singling "above a modest minimum", had either no effect on yield or else depressed it. In contrast with Woburn, the effect of cultivation did not vary with level of manuring. On the one occasion when pre-singling cultivations were given, the yield was increased. Russell said of the experiments at Woburn: "although the relative importance of pre- and post-singling operations may well depend on the vagaries of the weeds and the season, it is nevertheless clear from this experiment that if any plant nutrients and moisture are in short supply, quite modest weed competition may adversely affect the growth of young sugar beet plants and their ultimate yield".

Blackman and Templeman (1938) studying the effect of various weed species on the growth of cereals in the field, concluded that "in years of normal rainfall, competition between crops and weeds is principally for nitrogen and light, the magnitude of the latter depending on the weed species".

Bleasdale /

Bleasdale (1960) investigated the effect of various densities of three weed species on carrots, at two levels of fertiliser application. The highest weed density at high fertility gave the same yield as low fertility with no weeds present. He concluded that competition was mainly for nutrients.

(c) The effect of weeds growing in the crop row.

Bleasdale (1960) studied the effect on red beet of leaving a band of weeds co-incident with the row, at the same time carrying out normal inter-row cleaning, and also hand weeding with no inter-row cultivation. The presence of weeds significantly reduced the weight of tops and weight of roots, but the inter-plant weeds reduced the yield much less than the inter-row weeds.

Maddox (1958) compared yellow turnips precision sown at close spacing followed by singling, with those precision sown at wide spacing and left unsingled. The results in Table 9 show that the unsingled roots did not yield any lower than those singled or hoed.

Table 9. Yield of yellow turnips from spaced seeds, with and without singling - 1956 (Maddox - 1958)

Field No.	Unit set to sow at	Actual space between plants inches	Yield tons per acre
1	2-inch spacing singled	9.9	37.5
	6-inch spacing unsingled	8.5	36.0
2	4-inch spacing singled	10.0	24
	6-inch spacing unsingled	8.6	24
3	8-inch spacing hoed	10.4	25
	8-inch spacing unsingled	8.6	29
4	2-inch spacing singled	9.6	28.5
	6-inch spacing unsingled	8.0	28.0

Maddox drew attention to the fact that all these fields were fairly clean and free from weeds, and suggested that if weeds had been troublesome, yields from the unsingled plots might have been much lower. These results obtained by Maddox in Scotland are supported by NAAS trials in Breconshire (Edmunds, 1959). In one experiment, normal sowing and singling yielded 23 tons, 18 cwt. per acre; precision drilling at 1-inch spacing and singling yielded 22 tons, 19 cwt. per acre, and precision drilling at 6-inch spacing and no singling yielded 24 tons, 14 cwt. per acre.

Further reference to unsingled crops is made in the following section on sowing methods.

5. The Effect of the Method of Sowing.

Maddox (1958) precision sowed turnips at 1, 2, 3, 4, 5 and 8 inches, and found that the actual field spacing of the seed was greater than that intended. The unit set to sow at 1-inch spacing gave a spacing of 1.5 inches between plants; set at 4 inches, plant spacing was 6.5 inches, and set at 8 inches, plant spacing was 8.6 inches. It was found that in practice sowing turnips with units set to sow at 2-, 3-, and 4-inch spacing was satisfactory.

In four experiments to compare barrow-sown swedes and swedes precision sown at 2 inches, the barrow-sown swedes yielded 27.6 tons per acre at an average spacing of 10.0 inches, while the precision-sown swedes yielded 28.5 tons per acre at the same average spacing. In two of the trials 4-inch precision seeding was also included, and this gave almost identical results to the 2-inch seeding. Maddox's results with wider spacing and no singling have already been discussed.

In Wales, Prytherch (1959) compared barrow-sown swedes with those precision sown at 1-inch setting and singled, and those precision sown at 5- or 6-inch setting and left unsingled. The mean yields in terms of dry matter and the mean plant populations for the four centres are shown in Table 10.

Table 10 /

Table 10. Results of experiments at 4 centres to compare barrow-sown and precision-sown swedes (Prytherch 1959).

Treatment	Mean Yield (90% dry matter) tons per acre	Mean Plant Population '000 per acre
Farmer's drill (Singled)	2.02	24.7
Precision drill: 1-inch setting (singled)	1.97	24.8
Precision drill: 5- or 6 inch setting (not singled)	1.89	20.3

There was no significant difference in yield of swedes from the different treatments, despite a lower plant population per acre in the unsingled precision-drilled treatment.

Robertson (1959) carried out "a comprehensive series of experiments" on turnips and swedes sown with precision and non-precision seeders. The machines compared were set to sow at 3 1/2 lb. per acre, at 1-inch spacing, and at 2-inch spacing, on ridges which were rolled before and after seeding with a notched drill roller. With 1-inch spacings, the singling rate was increased by 30% compared with non-precision sowing, while with 2-inch spacing the increase was nearly 40%. The highest yields were obtained from the 1-inch seeding, followed by the non-precision seeding. The 2-inch spacing gave the lowest yield. The yields were in order of the plant population counts made immediately after hand-singling. Robertson (1961) stated, however, /

however, that after the experiment had been carried out for three seasons, it was found that the mean yields for swedes non-precision sown, sown at 1-inch spacing and at 2-inch spacing, were respectively 22.8, 24.3, and 23.7 tons per acre, and there was no significant difference between treatments.

In a series of experiments between 1957 and 1960, Holmes and Lang (unpublished) found that lateness in singling did not reduce the yield of turnip-barrow-sown swedes more than those precision sown. In 4 of the experiments the barrow-sown swedes gave a significantly lower yield of dry matter than those precision sown at 2-inch spacing, while in the remaining 2 trials, the yield differences were non-significant. In 3 out of 5 of the experiments in which precision seeding at 4-inch spacing was included, the barrow-sown swedes gave a significantly lower yield of dry matter than those sown at 4-inch spacing. Table 11 gives details of yields and plant populations for the three methods of sowing.

Table 11. /

Table 11. The mean yield of dry matter and the mean plant population of precision-sown and barrow-sown swedes - 1957 to 1960. (Holmes and Lang, unpublished)

Treatment	Average of 6 experiments		Average of 5 experiments	
	Yield of dry matter cwt. per acre	Plant population plants per acre	Yield of dry matter cwt. per acre	Plant population plants per acre
Precision drilled at 2-inch spacing.	64.1	21,500		
Barrow sown at 3 lb./acre.	62.5	23,000	60.4	22,600
Precision drilled at 4-inch spacing.			61.6	19,600

The results also showed that the average difference in yield between the early singled plants and those singled latest (when the plants had grown about 8-rough leaves) was 1 ton of roots per acre.

In recent work at the NAAS Experimental Husbandry farm of High Mowthorpe (Anon - 1961) swedes precision drilled at 8 inches without any hand work, gave just as large a crop as those grown on traditional lines. The seed was precision sown at 1 1/4 lb. of seed per acre and the land sprayed with Reglone or PCP (pentachlorophenol) six days later to control weeds. Clean land and excellent spacing were achieved by this method.

It was also shown that there was no reduction in yield when spacing was increased to 20 inches.

6. The Effect of Exposing the Hypocotyl when singling.

Rayns (1951) says that "a conscientious hoeman of the old school" was unsatisfied unless all the ground was moved in the process of singling. This moving of the soil mentioned by Rayns entailed 'couping' the seedling, and it is the traditional belief among many farmers that couping is important to the production of maximum yields, this view probably arising out of the need for the thorough cleaning of the crop when singling. The effect of couping on crop yield does not appear to have been investigated, but on theoretical grounds alone, the procedure would seem to have little to recommend it.

Caldwell (1929) studying the translocation of food material, examined the deposition of elaborated food materials in the swede bulb. He noted "if a swede had been thrown in the course of singling (that is, if it were lying flat on the ground) it subsequently developed a bulb, the long axis of which was inclined to lie parallel, rather than at right angles to the ground. Further, the side uppermost always developed to a greater extent than did the lower". Caldwell showed that the factor responsible for this development was the amount of carbohydrate transported to each of the sides. The leaves of the lower side of a 'thrown' swede were exposed less to the sun than those on the upper side, and the greater development of the upper side was du to the greater meta olism taking place in the upper /

upper and more exposed leaves, in conjunction with the absence of a transverse translocation taking place secondarily in the bulb.

In addition to the effect on metabolism, the growth habit of swede plants is an important factor from the point of view of mechanical harvesting. Robertson (1960) made it quite clear that the more obliquely the roots are lying, the less efficient is the work of the mechanical harvester.

Boyd (1958) found that the condition known as 'Strangles' occurred in sugar beet chiefly where the hypocotyl had been exposed, and where the plants were singled very early. Where plants were singled very carefully by hand without disturbing the soil around the plant, there was virtually no strangles. There was no consistent reduction in yield, however, even where strangles resulted in a loss of more than 10% of the plants, but Boyd emphasised that plant losses of this nature, might be serious where plant numbers were already low. Boyd (1962) stated that the condition is also prevalent in the swede crop, but to a lesser extent.

IV. EXPERIMENTAL.

The experiments carried out were designed to study the following factors affecting the growth and development of the swede seedling, and the subsequent effect of most of these factors on crop yield:

(a) the effect of seed size.

(b) the effect of fertilisers on emergence.

(c) the effect of weeds growing in the crop row.

(d) the effect of plant density and distribution.

(e) the effect of 'couping' the seedling when singling.

(f) the effect of sowing methods.

All the experiments were carried out on the farms of the Edinburgh School of Agriculture, 7 miles south-west of Edinburgh. The farms lie at an altitude of approximately 600 feet above sea level. On Boghall and Easter Howgate farms, the soils are variable but generally are a medium loam. The exposure is southerly, much of the land sloping downwards to the south-east. Yields of swedes in the region of 35 tons per acre can be expected in most seasons.

A. Meteorological Data.

The average rainfall at the Bush House weather station (situated on the estate) calculated over the 33-year period from 1928 to 1960 is 32.8 inches, and the average annual sunshine, 1313.4 hours.

Figure 1, Figure 2, and Figure 3 show respectively the weekly rainfall, sunshine and accumulated temperatures from April to December for the years 1959, 1960 and 1961.

1959 will long be remembered for the drought and sunshine over most of the country from May to September. After a cold start to the year there was an appreciable temperature excess from March onwards, and along with 1947, for Scotland as a whole, the period May to September ranked as the second warmest of the present century. Rainfall was extremely low, East Scotland being hardest hit by the drought. The weather continued dry for the first week or so of October, but rather wet weather followed. Persistent rain came in November and December - both very stormy months - and in parts of East Scotland, totals for these months reached double the seasonal average.

As in 1959, the opening two months of 1960 brought severe frost and snow. The weather in spring was mild and warm, with May the driest month of the year, and the mild sunny weather continued into June. July and August brought cool, unsettled and thundery weather. Rainfall /

Rainfall in August was considerably higher than average, and the autumn and early winter months were also wet and stormy. The total sunshine for the year was below average in the eastern part of the country.

Mildness was the main feature of the opening months of 1961, especially February and early March. Towards the end of March, however, in April, and even until the end of May, there were many sharp frosts. May was the driest month of the year but was also cold and windy, and the cold windy weather continued into June. July and August were cool and wet, the autumn mild but showery, while December brought low temperatures and severe snow blizzards. Taking the year as a whole, the East of Scotland was drier than average by approximately 10%.

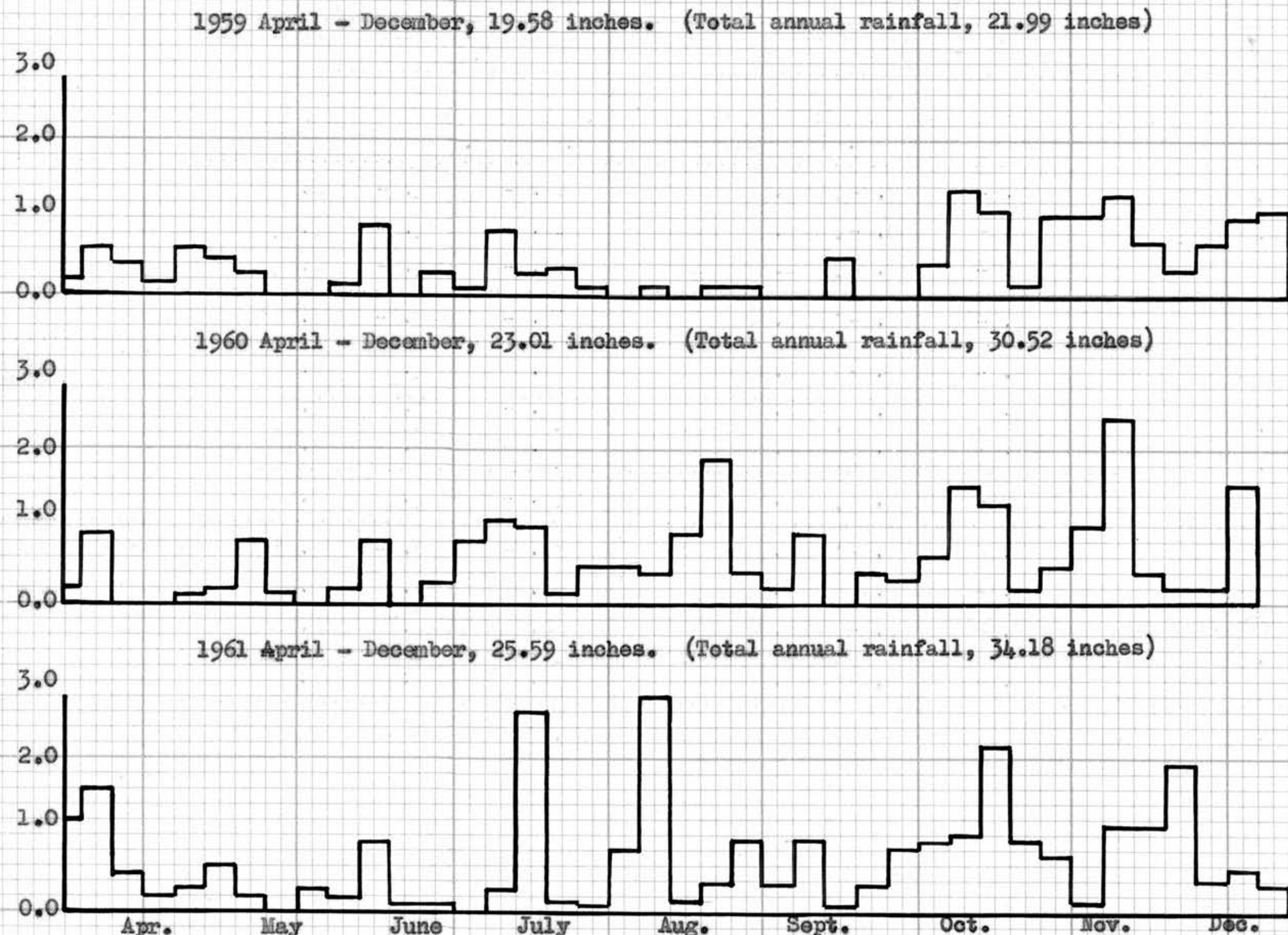


Figure 1. Rainfall - weekly totals in inches - April to December.

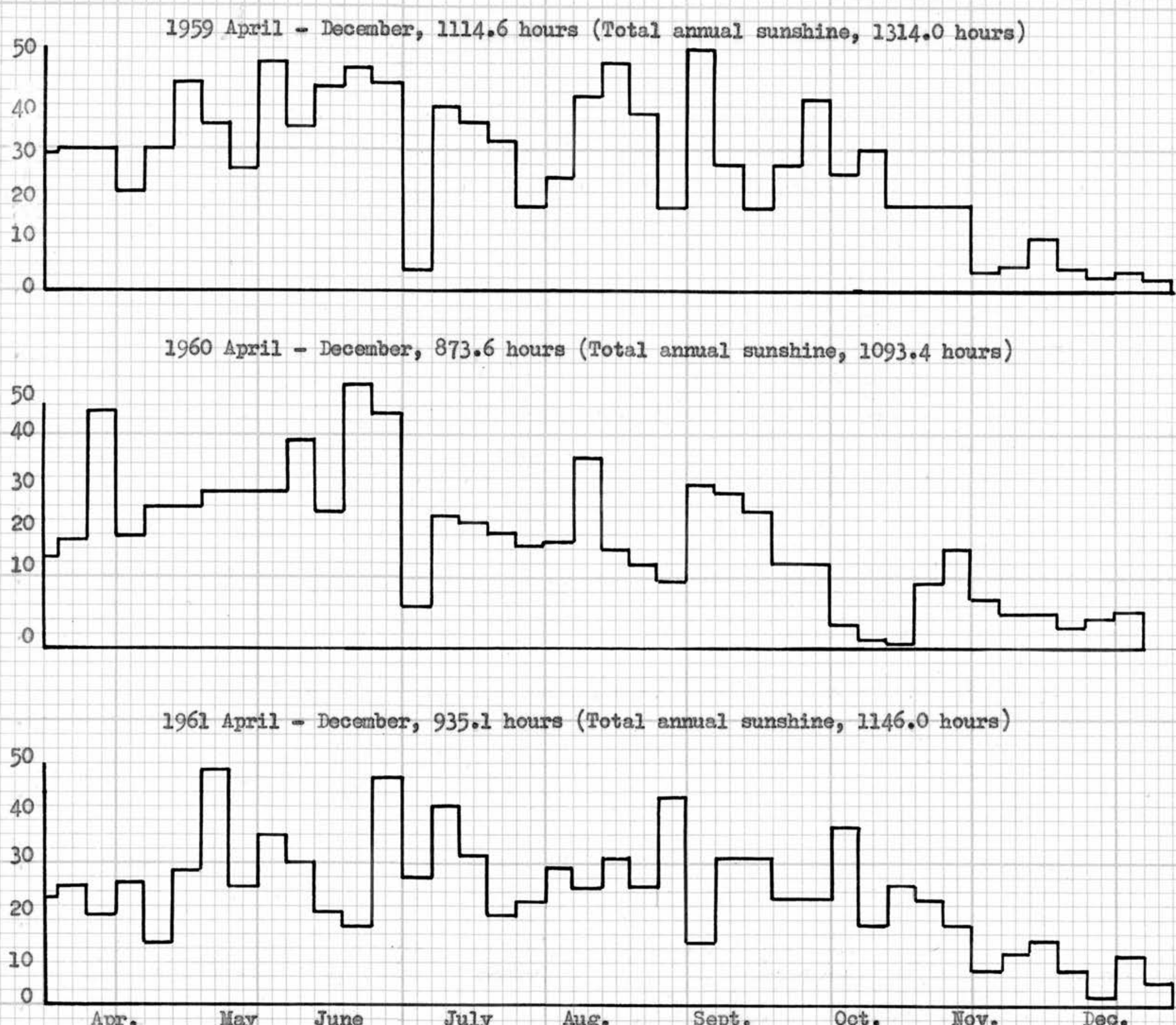


Figure 2. Hours sunshine - weekly totals, April - December.

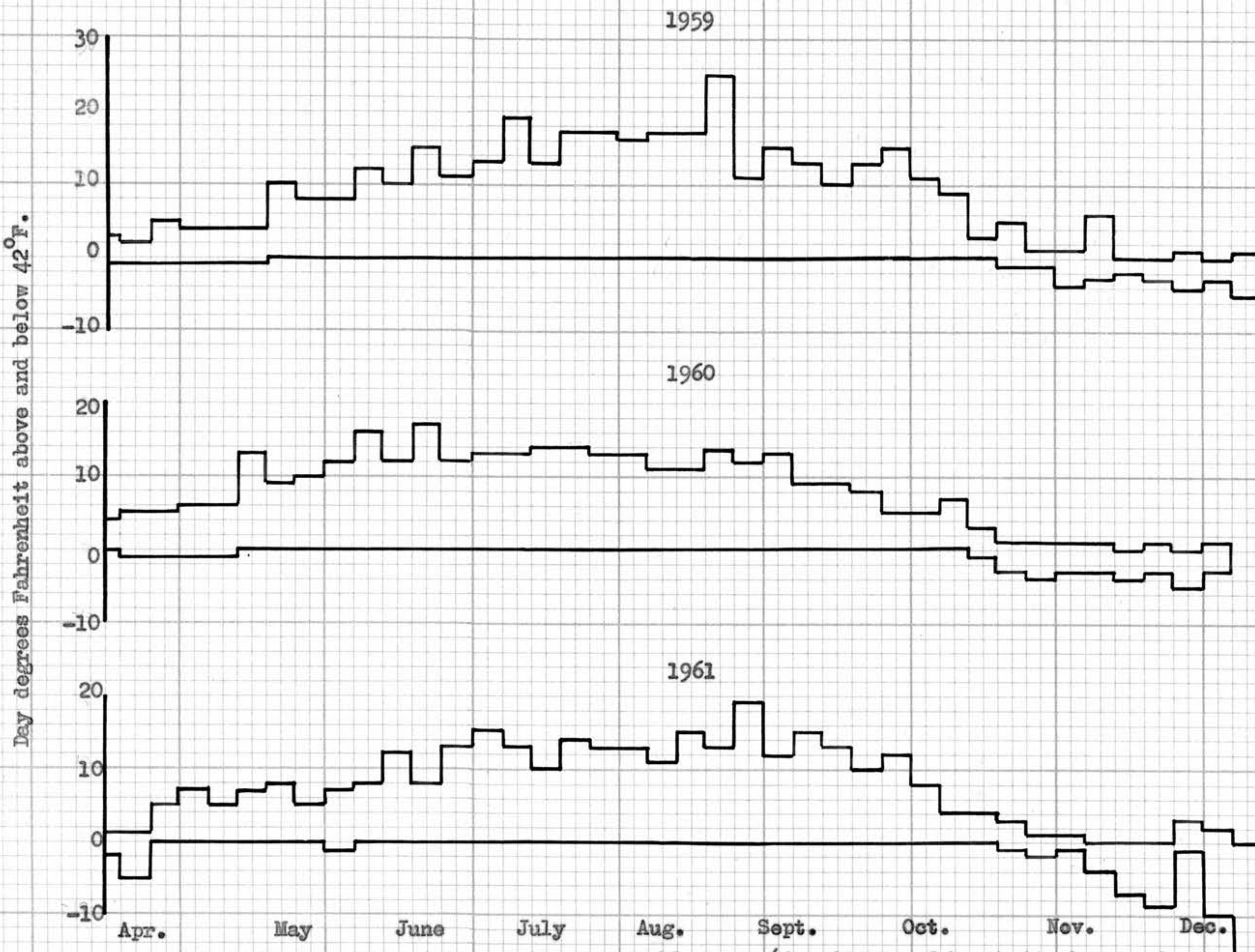


Fig. 3. Accumulated temperatures - weekly mean (day degrees fahrenheit above and below 42°F.), April - December.

B. Harvesting Procedure.

Sampling for dry matter:

The bulb of the swede is not uniform in composition, and this has an important bearing on the method of sampling. Hendrick and Greig (1904) divided a turnip into 12 portions and analysed each separately for dry matter. It was found that the upper half of the bulb contained a higher percentage of dry matter than the lower half, and that the outside next to the skin was richer in dry matter than the inner part. Proceeding from the outside inwards, the dry matter percentage fell. Fruwirth (1922) found a central slender column of tissue extending from the neck to ground level and having hardly half the value of the surrounding tissue in terms of dry matter, but Davey (1932) could find no trace of this low dry matter area.

Several methods of sampling have been tried. Davey (1932) stated that it was the practice in the last century to pulp a number of whole bulbs. Fruwirth (1922) sampled longitudinal sectors or wedges using a revolving rasp to cut and pulp simultaneously. Coring, however, has been the method most widely employed. Hendrick and Greig (1904) compared different methods of coring, and found that samples obtained by driving an auger "slantingly through the centre of the bulb from a point on the shoulder just at the edge of the leaf scar to a point near the tail" approximated to the true composition of the bulb as shown by taking wedges through the centre of /

of the bulb from top to bottom, and that this method of sampling was as accurate as any other method. Wood and Berry (1905) made a similar study with mangolds, but found that horizontal cores were better than diagonal ones, as the root changed in composition very quickly in the region just below the leaf scars. Robb and Wishart (1915) also used horizontal cores. Collins (1905) found that cores could be taken in any direction as long as they passed through the middle. Sansome (1926) studying suitable methods for sampling single swedes, cored roots in a North to South direction, and found the North half of the cores to be on average 1.58% dry matter units lower than the South half. This result is supported by Davey (1932). Davey also showed that the dry matter percentage of horizontal cores was approximately 95% of that of the whole bulb, and that diagonal cores gave closer values.

The procedure adopted in the present experiments was to sample 24 roots from each plot, 6 consecutive roots being sampled from each of 4 rows, the first root sampled in each row being chosen at random. This restricted randomization was adopted to overcome the practical difficulty of making completely random selections. Cores of ½-inch diameter were taken diagonally and always in the same direction - for convenience, at right angles to the crop row. The corer was inserted just outside the leaf scar area, and care was taken to include both ends of the core in the sample and to remove any earth adhering to the core ends. The cores were taken in polythene /

polythene bags to the laboratory where the cores were cut into 2-inch lengths and dried at 80 to 85 degrees Centigrade for 48 hours.

Counting and Weighing:

At harvest, the roots were pulled and topped leaving approximately 1 to 2 inches of 'neck', and tailed to remove adhering dirt. Each block was topped by one operator. Diseased roots and healthy roots were counted and weighed separately. The roots were weighed to the nearest ½ lb. on a platform balance (weighing up to 500 lb.) mounted on a steel frame which was supported by two rubber-tyred wheels and a draw arm to facilitate movement from plot to plot. The roots were filled into a specially constructed basket having a frame of steel strips filled in with heavy gauge wire mesh. The dimensions of the basket were 24 inches x 30 inches x 30 inches - sufficient to contain over 500 lb. of roots. After weighing, the free side of the basket was removed and the roots tipped out.

The tops were forked onto a canvas sheet and weighed to the nearest ½ lb. on a spring balance suspended from a weighing arm.

C. The Effect of Seed Size on Germination, Emergence, Seedling Growth and Crop Yield.

<u>Introduction</u>:

In the early years of precision seedling, the production of graded seed involved riddling off a total of approximately 5% of 'rough' seed and 'siftings', the remainder being regarded as graded seed. In 1960 this degree of tolerance was reduced by agreement between seedsmen and implement manufacturers, so that at the present time, approximately 50% of the original bulk of seed constitutes graded seed, the percentage removed at the 'top' and the 'bottom' varying among varieties and among different samples of the same variety.

<u>Method</u>:

Between 1959 and 1961 a number of experiments were carried out to compare seeds of three sizes.

(a) The main experiment concerned chiefly with crop yields, 1959 to 1961.

(b) Laboratory germination tests, 1959 to 1961.

(c) Emergence test, 1960.

(d) Growth study to measure emergence, cotyledon area, and seedling leaf area, 1961.

Three sizes of seed were used in the experiments. In 1959 the three size groups were obtained by hand riddling, the middle size being classified as 'medium' seed. The riddles used were designed /

designed to the British Standard Specification (B.S. 410 - 1943). The large seed was that stopped by a riddle having 12 holes to the inch, medium seed was that passing through 12 but being stopped by 14 holes to the inch, and small seed was that passing through 14 holes to the inch. In 1960 and 1961 the three size groups were graded seed and those portions of the seed removed from the 'top' and the 'bottom' in the course of commercial grading. The range of seed sizes in the graded seed was .067 - .077 inches diameter.

(a) Main experiment.

The experiment was carried out between 1959 and 1961 and in each year took the form of four replications of a 3 x 4 factorial in a randomized block design. Three seed sizes were compared in all three years. In 1959 and 1961, the second factor involved was plant spacing, and in 1960, it was varieties. Treatments were as follows:

1959	1960	1961
Seed Size	Seed Size	Seed Size
L - large	L - large	L - large
M - medium	G - graded	G - graded
S - small	S - small	S - small
Mean Spacing	Variety	Mean Spacing
1 - 5 inches	B - Best of All	1 - 5 inches
2 - 8 inches	V - Victory	2 - 8 inches
3 - 11 inches	P - Peerless	3 - 11 inches
4 - 14 inches	U - Superlative	4 - 14 inches

In order to sow an equal number of seeds of each grade,

500 /

Table 12. Seed variety and grade, the weight of 1000 seed, and the number of seed sown per plot.

Year	Variety	Grade	Percentage of original seed	Weight of 1000 seed	Number of seeds sown per plot
1959	Victory	Large	38	3.417	3044
		Medium	70	2.608	
		Small	2	1.592	
1960	Best of All	Large	63	4.613	2000
		Graded	34	3.156	
		Small	3	2.099	
	Victory	Large	25	4.208	
		Graded	66	3.034	
		Small	9	2.149	
	Peerless	Large	35	3.996	
		Graded	60	3.128	
		Small	5	2.163	
	Superlative	Large	42	3.968	
		Graded	44	3.058	
		Small	14	2.298	
1961	Victory	Large	47	3.988	2000
		Graded	39	3.118	
		Small	14	2.239	

500 seeds of each were counted out and accurately weighed. From this was calculated the weight of seed of each size group necessary to sow the same number of seeds per plot. Table 12 gives details of the seed sown in each year of trial. The seed was weighed out into bottles, and dusted with "Fytolex" dressing against flea beetle attack. In each of the three years, the experiment was carried out on the demonstration plots at Bush House, four plots each 1/16 acre accommodating the experiment. Details of preceeding crops, fertiliser applications, and soil analyses are given in Appendix A.

The experimental area was ploughed in early spring each year, and rotavated and harrowed at the end of April. The fertiliser was broadcast and harrowed in. The demonstration plots were marked out in 20-inch rows making small furrows approximately 3 inches deep, and the experimentalplots defined by cross strings. The plots were arranged in 3 rows of 4 within each demonstration plot, and plot size was approximately 1/250 acre, being 6 drills wide and 17 feet long. The two outside drills of each demonstration plot were left as guard rows, and 2 feet at each end of the drills were also discarded. An equal number of seeds per plot were then sown on the flat by hand, and the furrows covered and rolled with an empty hand seeder.

Conditions at sowing were very dry both in 1959 and 1960. In 1959 some rain fell shortly after sowing, and emergence occurred within 7 days. In 1960, after sowing on the 5th May, the dry spell remained /

remained unbroken until the 13th May and it was the 19th May before the first signs of emergence occurred. In 1961, the seed went into a warm moist seed bed on the 4th May and emergence occurred after 6 days.

Emergence counts were taken in 1959. Since the seed was sown by hand, sampling was not considered very satisfactory, and all plants emerging in the plots were counted at 9 and 14 days after emergence commenced, the last date of counting being just before singling. In 1960 and 1961, since separate trials were put down to obtain information on emergence, an estimation of the emergence percentage was obtained by counting sample lengths when emergence appeared to be complete. Two 2-feet lengths were chosen at random from each of the 6 rows of every plot by throwing down a 2-feet long cane, all plants along the length of the cane being counted. This gave a sampling percentage of 12%.

Singling was carried out when the seedlings had produced, on average, 3 foliage leaves. This was done by hand and the required plant spacings were obtained using pieces of cane cut to length. In 1960 when plant spacing was not a treatment, plants were singled to 8-inch spacing.

At approximately 2 and 4 weeks after singling, the length of the first foliage leaf was measured on 8 plants selected at random from each plot, measuring from the leaf tip to the base of the petiole. The number of leaves on each plant was also noted.

Dates /

Dates of sowing, singling, and harvesting are given in Appendix A.

(b) Laboratory Germination Tests, 1959 to 1961.

A germination test was carried out on a sample of 100 seeds of each of the three sizes of seed used in the main experiment in 1959 and 1961. In 1960, a similar test was done on each size of the 4 varieties. Additional tests were carried out in 1961 with further samples of 3 of the varieties tested in 1960. A Copenhagen germination tank was used in these tests, the seed germinating at a temperature between 20 and 30 degrees Centigrade. In 1959 and 1961 the first count was made the day after germination commenced, and further counts were made on the following six days, after which germination was assumed to be complete. In 1960 counts were made only on the 4th and 7th days after germination commenced.

(c) Emergence Test 1960.

The purpose of this small experiment was to find out how seed size affects the rate of emergence and the emergence percentage.

The experimental design was a randomized block consisting of five replications of a 3 x 4 factorial layout similar to the main experiment of the same year, in which 3 seed sizes of each of 4 varieties were compared. The experimental plot consisted of a 3-feet long 'groove' in the soil approximately 1 inch deep in which were sown 50 seeds of the appropriate seed size and variety. Care was taken in forming the grooves and in covering the seed, that the sowing depth was as uniform as possible.

Emergence counts were made daily from the first signs of emergence for the first 4 days, and thereafter every second day until emergence was complete.

(d) Emergence Test 1961. Measurement of Cotyledon and Leaf Areas.

Apart from providing further information on the rate of emergence and emergence percentage, the purpose of this experiment was two-fold:

(i) to examine the relationship between the length of the first foliage leaf and its area, and the length of the first foliage leaf and the total leaf area of the plant. This is discussed under "Leaf Length as an Indication of Growth". (Section H)

(ii) to compare the cotyledon areas of plants from 3 sizes of seed, and the leaf areas of these plants at 4 stages of growth.

Six replications of a 3 x 3 factorial layout were put down, in which the treatments were 3 seed sizes, the plants from the different sized seeds being measured at three stages of growth. The seed sizes used were the same as those used in the main experiment of the same year.

The experiment was laid down on a 1/16 acre plot at Bush House. The plot was ploughed in early spring and rotavated at the end of April. The fertiliser was broadcast and harrowed in, and the plot marked off in 20-inch rows. The demonstration plot was divided by means of twine into 6 strips 7 feet wide running across the line of the /

the marked rows, the experimental plot consisting of 3 rows, 7 feet long and 20 inches apart. The central row of each plot was sown with exactly 100 seeds, while in the 2 outer rows approximately 100 seeds were sown. The seed was covered uniformly and the crop rows were rolled with an empty hand seeder. The seed was sown on the 9th May in a moist seed bed. Sowing was followed by a warm dry spell and the first few plants appeared on the 17th May. Emergence counts were made on the middle rows every two days until emergence was complete.

On the 22nd May, 6 pairs of cotyledons were picked out at random from the middle row of each plot and their areas determined by means of light-sensitive paper and a planimeter. An outline of the procedure is given below. On the 4th June, before singling, 3 plants were chosen at random from the middle row of every plot, and their area determined. The following day the experiment was singled to 8-inch spacing which left 9 plants in each plot row. Three plants were sampled from the middle row of the appropriate plots on the 11th, 17th and 23rd June, discarding the first plant in the row and taking the next three. Restricted sampling was used to enable further samples to be taken at a later date if required. Leaf areas were determined by the same procedure used with cotyledons. A week after the final sampling the 6th plant in the middle row of each plot was isolated, i.e., the plant next but one to the blank space created by sampling, and all plants around the selected plants were /

were removed to a distance of approximately 6 feet to ensure that the selected plants were growing in a non-competitive environment. The plants were covered with netting for a short period as a protection against birds, and were finally harvested on the 25th November. The yield of dry matter for each plant was estimated by drying the whole of the top and a wedge cut from the root.

Procedure for Determination of Cotyledon and Leaf Areas.

After sampling, the cotyledons or leaves were taken to the laboratory, spread out on light-sensitive paper (ferro-prussic paper No. 23), covered with glass and exposed to the light. The amount of exposure required varied from 10 seconds in bright sunlight to 90 seconds under fairly dense cloud cover. The glass was removed and the paper immersed in water. The exposed area showed as a blue background and those areas covered by the cotyledons, as sharply defined white areas.

With the leaves, it was necessary to press them between sheets of blotting paper to flatten the petiole before preparing for exposure. The procedure became more difficult as the leaves enlarged, due firstly, to the thickness of the petiole causing a 'fuzziness' of outline, and secondly, to folding of the leaves and overlapping of the laminae. This method is unlikely to be very successful with plants having more than 6 or 7 leaves. A planimeter was used to measure the leaf areas, readings being made to 1/100 square inch.

Statistical Analysis.

The /

The simple randomized block designs used, present no problems, but where a single analysis of variance was constructed to test the effect of seed size over the three years, the procedure is complicated by the fact that spacing occurred as the second factor in two years while varieties occurred in one year. The division of the degrees of freedom is given below.

Source of Variance		d.f.
Total		143
Years		2
Replicates/years		9
Seed Size		2
Seed size x years		4
Spacing and varieties/years		9
Seed size x varieties	6)	
Seed size x spacing	6)	18
Seed size x spacing x years	6)	
Error		99

Results:

1. Germination and emergence.

Table 13 gives the germination percentage obtained in 9 tests carried out between 1959 and 1961.

Table 13 /

Table 13. The effect of seed size on germination percentage in 1959, 1960 and 1961.

Year	Variety	Percentage Germination		
		Large seed	Graded seed	Small seed
1959	Victory	91	91	94
1960	Victory	89	88	92
	Best of All	96	97	97
	Peerless	97	97	97
	Superlative	95	96	95
1961	Victory (a)	96	98	99
	Victory (b)	98	97	98
	Best of All	98	99	99
	Peerless	99	100	98
Mean		95	96	96

S.E. of the mean (seed sizes) = $\pm$ 0.4%

There was no significant difference in germination percentage between the three seed size groups.

A Rate Index (page 104) was calculated for those tests carried out in 1959 and 1961, and differences between the seed sizes were again non-significant. Expressing the mean Rate Index as "germination speed %", that is,

$$\frac{\text{Average germination over test period}}{\text{Final germination}} \times 100 \text{ (Leggatt and Ingalls 1949)}$$

the /

the large, graded and small seeds gave 'speeds' of 79.8%, 81.2%, and 81.7% (S.E. = 2.2%).

Table 14 gives the percentage of plants emerged both in the main experiments and in the emergence tests in 1959, 1960 and 1961.

Table 14. The mean emergence percentage from the three sizes of seed in the main experiments and in the emergence tests in 1959, 1960 and 1961.

	Percentage Emergence			
	Large seed	Graded seed	Small seed	S.E.
Main experiment, 1959	58.1	61.6	52.5	± 0.9
Main experiment, 1960	76.1	77.9	75.3	± 0.6
Emergence test, 1960	78.1	80.8	77.4	± 1.6
Main experiment, 1961	75.1	73.7	72.7	± 0.6
Emergence test, 1961	78.1	80.7	78.4	± 0.6
Mean	73.1	75.0	71.3	

In 1959, the small seed gave a significantly lower emergence percentage than the large seed, while the large seed was significantly lower than the graded ($P = .05$).

In the main experiment in 1960, the small and the large seed again gave a significantly lower emergence than graded seed ($P = .01$) and there was a very similar trend in the emergence test of the same year, although the treatment differences were non-significant. The seed size x variety interaction was significant at the 1% level in /

the main experiment, but did not approach significance in the emergence test. Table 15 shows the appropriate two-way table from the main experiment.

Table 15. The mean emergence percentage in the main experiment in 1960. Seed size x variety.

	Best of All	Victory	Peerless	Superlative	
Large seed	76.8	77.9	76.9	72.8	
Graded seed	80.2	77.5	82.1	71.9	S.E. = $\pm$1.2
Small seed	75.3	78.1	74.0	74.0	

There was no significant difference between seed sizes in either of the experiments in 1961.

A Rate Index was calculated from the two emergence counts made in the main trial in 1959, and the emergence tests in 1960 and 1961, and in no instance did the emergence rates from the different seed sizes differ significantly, the mean Rate Indices of the three years being .790, .792, and .782, for the large, graded and small seed respectively.

Varieties - 1960: The emergence percentage for the four varieties was significantly different at the 1% level in the main experiment, and at both the first and final counts in the emergence test. Differences in emergence percentage among the varieties were considerably greater at /

at the first count than at the final one, suggesting differences in emergence rate, and this was borne out by analysis of the emergence Rate Index when differences in emergence rate were shown to be significant at the 1% level. Table 16 gives details of the emergence counts for the four varieties.

Table 16. The mean emergence percentage of the four varieties in the main experiment in 1960, the mean emergence percentage at the first and final count in the emergence test, and the mean Rate Index.

	Best of All	Victory	Peerless	Superlative	S.E.
1. Emergence test, first count	41.3	14.9	30.7	14.9	± 2.4
2. Emergence test, final count	82.5	76.3	81.5	74.8	± 1.8
3. Main experiment	77.3	77.8	77.7	72.9	± 0.7
4. Mean of 2 and 3	79.9	77.1	79.6	73.8	
5. Rate Index	.842	.687	.789	.706	± .014

On average, Superlative was inferior in emergence percentage to the other varieties. Best of All gave the highest emergence rate.

Discussion:

The results of the germination tests give no reason to believe that the germination percentage or the rate of germination was influenced by the size of seed, and this agrees with the results of Leggatt and Ingalls (1949). Schmidt (1921) found that the germination of heavy crimson /

crimson clover seed was higher than that of lighter seeds and that the heavy seeds germinated slightly earlier. Schmidt's tests, however, were based on a very small number of seeds, namely, 15 seeds of each weight group, so that too much reliance cannot be placed on his results. Any differences which may occur in the germination percentage or in the rate of germination of swede seeds of different sizes is, therefore, likely to be very small and of no practical importance.

The literature provides little information on the effect of seed size on emergence, but Cummings (1914) in 16 trials with radish, obtained 104% more plants with large seed, and in another series of trials comparing three sizes of radish, the large seed gave 74% emergence, the medium seed 70%, and the small seed 49%. Although no actual measurement of emergence was made by Leggatt and Ingalls (1949) in experiments with five sizes of Laurentian swede seed, three plots in their experiment had so few roots that they were not acceptable for analysis of results. All three were from the smallest sized seeds. They also observed that "in the field" stand was adversely affected where small seed was sown.

Results of the present experiments agree with these results to the extent that the small seed invariably gave a lower emergence percentage than the large seed, but there is rather strong evidence from the present experiments that the graded was superior in emergence percentage to the large seed, being higher in 4 experiments out /

out of 5 and giving on average 75% emergence, compared to 73% for the large seed and 71% for the small. The significant variety x seed size interaction, however, gives some reason to believe that the superiority of graded seed, or of large over small, is a varietal characteristic and may not apply to all varieties.

It is interesting to note that the low average emergence which occurred in the very dry conditions of 1959, coincided with comparatively large treatment differences, which does suggest that the effect of seed size on emergence is dependent to some extent on conditions at sowing - particularly the soil moisture content. The depth of sowing also undoubtedly has some effect on the emergence of plants from different sized seeds, for Black (1956) showed that there was a depth beyond which small clover seeds could not emerge, but from which the emergence of larger seeds was unimpaired.

It would seem from the 1960 experiment that differences in emergence percentage and rate of emergence can be expected from different varieties. These differences, however, may be largely due to differences between samples of seed grown in different areas and under different conditions.

2. <u>Growth of the seedling.</u>

From emergence, differences in the size of the plants from the different sized seeds were easily discernible in each of the three years. In the first two years, the plots were scored for plant size around the 2-rough leaf stage, and in both years the plants from the large /

large seed were clearly superior to those from the graded seed, which in turn were superior to those from the small seed. The position in 1961 was similar, although differences in the average size of the plants from the different sized seeds were a little less distinct.

Cotyledon and leaf areas: Similar observations to those made in the main experiments each year were made in the growth studies (Experiment (d), 1961) carried out to measure the cotyledon and leaf areas from 3 sizes of seed. Details of the cotyledon and leaf areas obtained in this experiment are given in Table 17.

Table 17. The mean cotyledon areas of plants from 3 sizes of seed, and the mean leaf areas of the plants at 3 stages of growth.

	Area (square inches)			
	Large seed	Graded seed	Small seed	S.E.
Cotyledons	0.23	0.19	0.11	±0.008
Leaves at singling	3.02	2.56	1.92	±0.29
Leaves, 1 week after singling	11.06	10.17	8.10	±0.50
Leaves, 2 weeks after singling	21.78	17.32	14.49	±0.81

The differences between the cotyledon areas of the plants from the different sized seeds and the leaf areas measured before singling were /

were significant at the 1% level, while differences in the leaf areas at 1 and 2 weeks after singling were significant at the 5% level.

Growth rate: Further examination of the data from the growth studies reveals that the area of the cotyledons from the 3 seed-size groups, and the leaf areas of the plants measured at 3 stages of growth were approximately in the same proportion as the seed weights. Table 18 gives the seed weights, cotyledon areas and leaf areas of the plants from the small and graded seed as a percentage of those from the large seed.

Table 18. The seed weights, cotyledon areas and leaf areas of plants from small and graded seeds as a percentage of those from large seed.

	Small/large per cent.	Graded/large per cent.
Seed weight	60	80
Cotyledon area	66	83
Leaf area before singling	63	84
Leaf area 1 week after singling	73	91
Leaf area 2 weeks after singling	66	79

The plants from the 3 seed-size groups maintained approximately the same relative growth rate. This was confirmed for the leaf area measurements by the analysis of the growth Rate Index which was calculated using /

using 3 dates of leaf area measurement. In the pre-singling measurement, the mean of the three large, graded, and small plots in each block was taken. The growth Rate Indices were .565, .582, and .581 for the large, graded and small seed respectively, the differences being non-significant.

The cotyledon and total leaf areas are presented graphically in Figure 4, and again after logarithmic transformation in Figure 5, in which it can be seen that the growth lines are virtually parallel, indicating approximately equal growth rates.

The leaf length measurements taken in the main experiments each year at approximately 2 and 4 weeks after singling, provide further information on the growth of the seedlings. At 2 weeks after singling (at 6-7 rough leaf stage) in each of the 3 years, the plants from the small seed were significantly smaller than those from the graded and large seed ($P = .01$). On average, the plants from the small seed were 87% of those from the large seed. At 4 weeks after singling (11 - 12 rough leaf stage) treatment differences were again significant at the 1% level in 1959, but non-significant in 1960 and 1961, and plants from the small seed were, on average, 97% of those from the large seed. The leaf length data are given in Table 19. Four weeks after singling, the plants from the large seed had clearly lost much of their superiority in size over the plants from the small seed. The plants from the graded seed, however, were not significantly smaller than those from the large seed at either the 6- or 12-rough leaf stage/

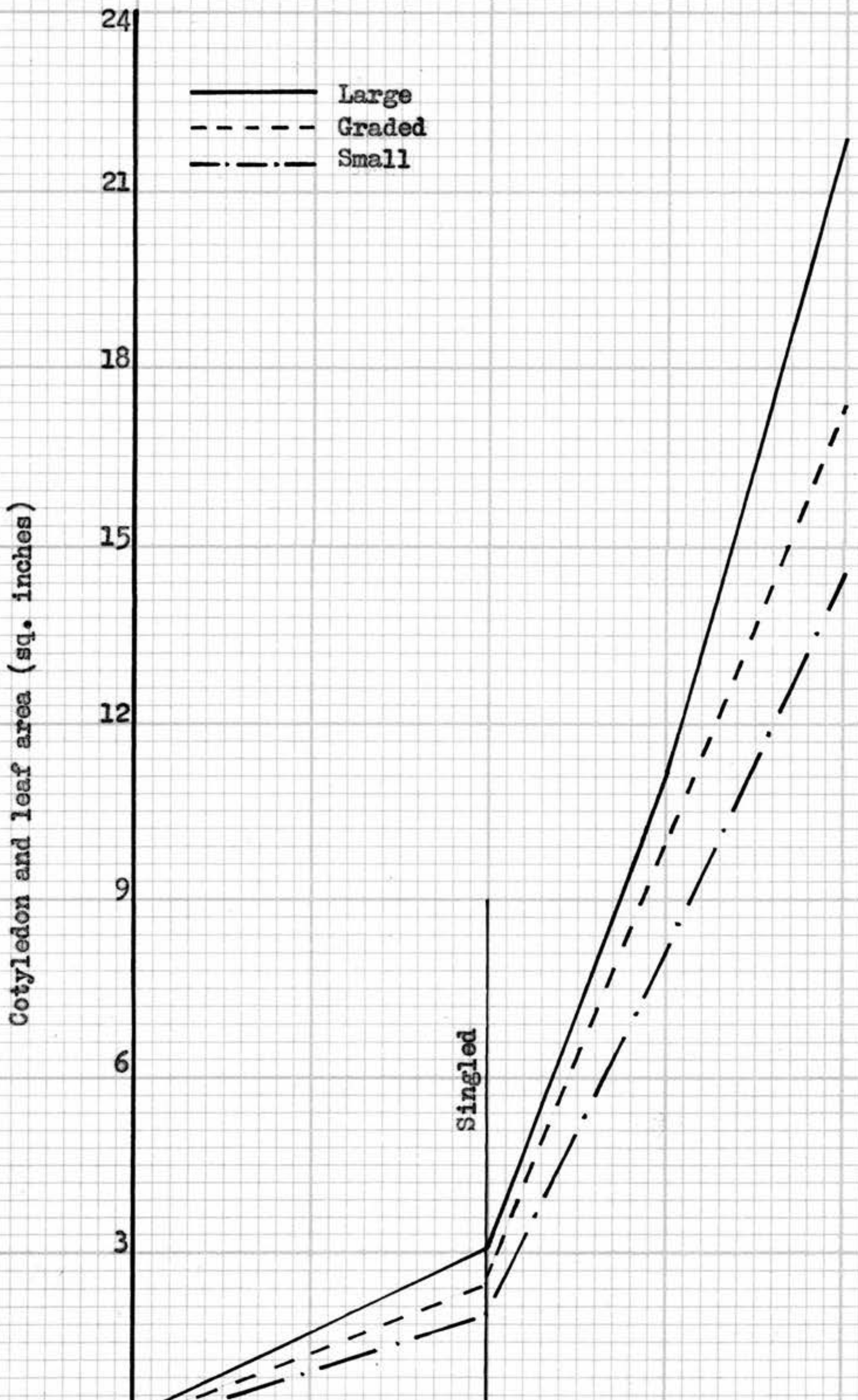


Figure 4. The area of the cotyledons and the total leaf area at 3 stages of growth, of plants from 3 sizes of seed.

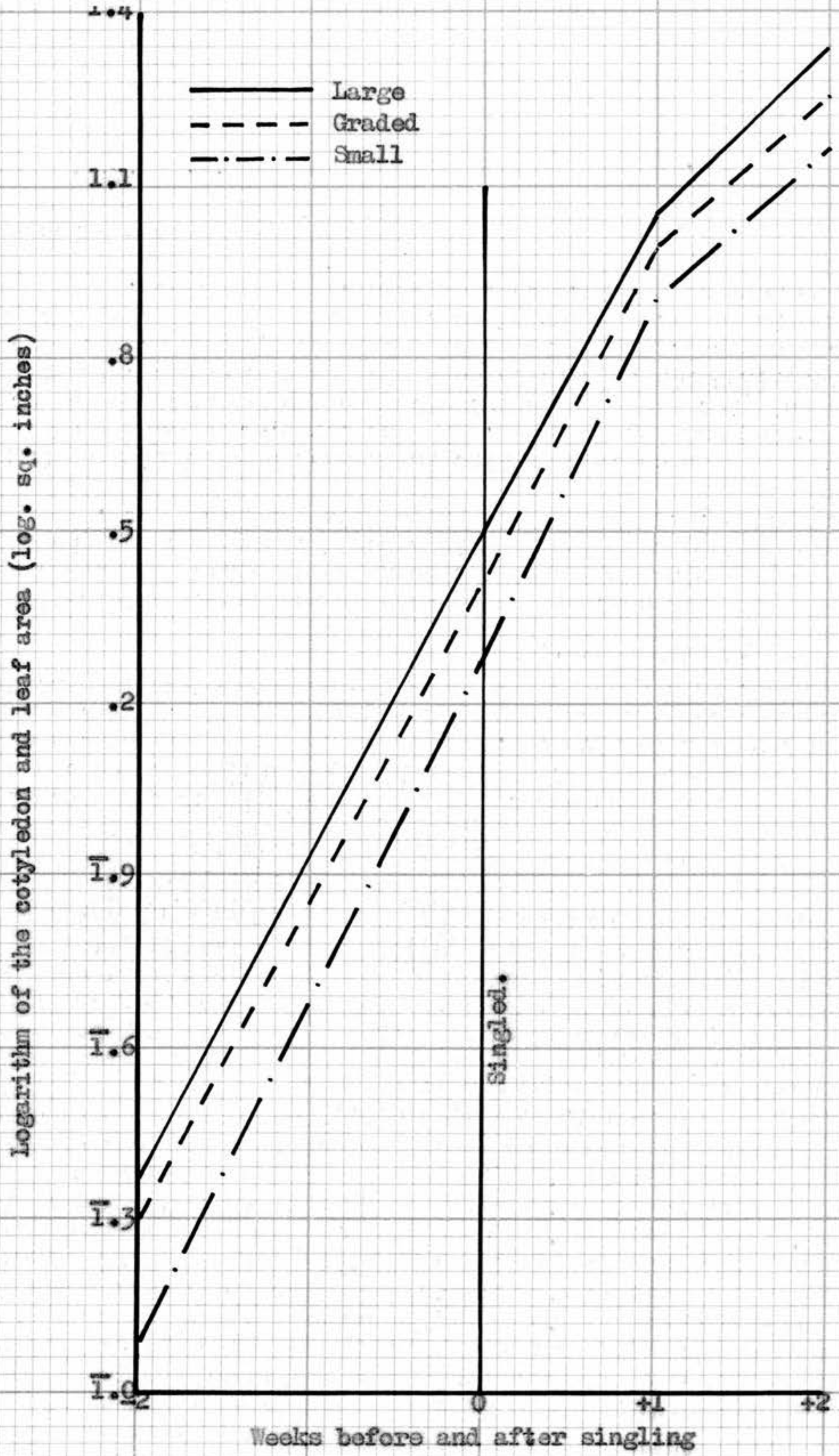


Figure 5. The logarithm of the cotyledon area, and the total leaf area at 3 stages of growth, of plants from 3 sizes of seed.

Table 19. The mean length of the first foliage leaf of plants from 3 sizes of seed measured at 2 and 4 weeks after singling in 1959, 1960 and 1961, and the leaf length of the plants from the small seed expressed as a percentage of that from the large.

Year	Seed size	Leaf length (cm.) 2 weeks after singling	Leaf length (cm.) 4 weeks after singling
1959	Large	14.5	42.1
	Medium	14.4	40.3
	Small	12.5	39.0
Small as a percentage of large		86	93
1960	Large	12.6	43.0
	Graded	12.6	42.6
	Small	10.9	43.7
Small as a percentage of large		87	101
1961	Large	13.6	28.4
	Graded	13.2	28.6
	Small	12.1	27.8
Small as a percentage of large		89	98
Small as a percentage of large - 3-year mean		87	97

stage in any of the years, being an average 98% of the large seed at both stages of growth.

In 1959 and 1961, when four spacing distances were included in the experiment, there was no evidence at either the 6- or 12-rough leaf stage that the amount of space given affected the relative growth pattern from the different seed sizes. Nor was there an interaction between seed size and variety in 1960.

<u>Plant spacing</u>: In 1959, the effect of the spacing treatments on leaf length 2 weeks after singling was significant at the 5% level, and 4 weeks after singling was significant at the 1% level. The closest spaced plants were significantly longer than the wider spaced ones. This may have been a matter of length rather than area for although the length/area correlations (Section H) showed a close association of the two factors, it was stressed that the regression of length on area was likely to be affected by environment, particularly spacing.

The varieties showed no significant difference in leaf length at either stage of growth.

As far as the number of leaves per plant is concerned, the only significant effect was at the earlier stage of growth in 1960, although there was a similar but non-significant effect in 1961. The average number of leaves per plant 2 weeks after singling was 6.7, 6.5 and 6.3 for the large, graded and small seeds respectively. At the latter stage of growth, the numbers of leaves per plant were /

were virtually the same.

3. <u>Main experiment. Plant numbers and the numbers of sound roots harvested.</u>

Details of plant numbers and the numbers of sound roots harvested are given in Table 20. In none of the years was the number of plants remaining after singling significantly affected by the size of the seed. The use of small seed in 1959, however, significantly reduced the number of roots harvested ($P = .05$), but in 1960 and 1961 there were no significant effects on root numbers.

Table 20. The mean plant population after singling and the mean number of sound roots harvested, for the 3 sizes of seed in 1959, 1960 and 1961.

Year	Large seed	Graded seed	Small seed	S.E.
	Number of plant per acre after singling			
1959	37,504	37,856	36,832	± 333
1960	32,640	31,856	32,560	± 282
1961	37,008	36,672	37,008	± 410
	Number of sound roots harvested per acre			
1959	34,960	34,320	33,008	± 538
1960	29,664	28,976	29,232	± 358
1961	34,656	34,880	35,200	± 307

The lower number of sound roots harvested from the small seed in 1959 was /

was largely the result of the lower plant population after singling, itself a result of lower emergence, but a higher mortality rate and a large number of diseased roots were also contributory.

Mortality rate can be defined as the difference between the number of plants at the post-singling count and the total number of roots harvested, expressed as a percentage of the former. The differences in mortality rate failed to approach significance in any of the years and were virtually the same on the average of the 3 years (Table 21).

Table 21. The mortality rate of plants from 3 sizes of seed in 1959, 1960 and 1961.

	Mortality Rate (per cent.)			
Year	Large seed	Graded seed	Small seed	S.E.
1959	2.8	4.0	4.6	± 1.1
1960	7.3	5.9	7.2	± 1.1
1961	4.6	4.8	3.1	± 0.9
Mean	4.9	4.9	5.0	

Since only 12 diseased roots were found throughout the whole trial area in 1961, only the first two years provide any information on disease incidence. Table 22 shows the number and weight of diseased roots in 1959 and 1960.

Table 22 /

Table 22. The number and weight of diseased roots from the 3 seed sizes in 1959 and 1960.

	Large seed		Graded seed		Small seed	
	Number plants per acre	Weight cwt. per acre	Number plants per acre	Weight cwt. per acre	Number plants per acre	Weight cwt. per acre
1959	976	13.8	960	15.2	1200	19.1
1960	656	13.1	1040	21.7	896	18.0
Mean	816	13.4	1000	18.5	1048	18.5

On average, the large seed gave approximately 27% less diseased roots than the graded or small seed, but this difference was non-significant by the chi^2 test carried out on the treatment totals of the 1959 and 1960 experiments. There was no significant evidence, therefore, that the incidence of disease was affected by the size of the seed.

In 1960 the variety x seed-size interaction for the number of roots remaining after singling was significant at the 5% level. This interaction was almost certainly a result of the significant variety x seed-size interaction for emergence percentage.

None of the plant spacing x seed-size interactions was significant, but this interaction came very close to significance for the post-singling plant count in 1959 (V.R. = 2.32; $F_{.05}$ = 2.38) when the graded seed gave a higher number of plants that the small or large seed at close spacing but had little effect on plant numbers at wider spacing.

It is only to be expected that the higher emergence

percentage /

percentage of the graded seed in this year should affect plant numbers at close spacing yet not at wider spacing.

In the literature, no consideration has been given to the effect of seed size on disease incidence, and the only reference to mortality rate was made by Oexemann (1942) working with tomato, soya bean and cucumber. Oexemann observed that the mortality rate appeared to be higher among plants from lighter seed compared to those from heavier seed. The present results, however, fail to show that mortality rate or the incidence of disease in swede plants is influenced by the size of the seed from which they originate.

4. Crop yield.

Crop yield data are given in Table 23. In 1959, differences in the yield of roots were significant at the 5% level, and in the yield of dry matter at the 1% level. The large seed yielded 2.0 tons of roots per acre more than the small seed, and 1.4 tons per acre more than the graded seed, corresponding to differences in dry matter yield of 6.4 cwt. per acre, and 4.0 cwt. per acre respectively. When the yield of roots was adjusted for differences in the number of sound roots harvested by means of covariance analysis, the variance ratio for the main effect of seed size was reduced from 3.37 to 2.12 (which was non-significant) but it is unlikely that differences in the number of roots harvested had any influence on the effect of seed size on yield, since the plant spacing treatments included in the experiments (giving populations varying from 22,000 up to 50,000) gave no indication /

Table 23. The yield of sound roots, the dry matter percentage of the roots, the yield of dry matter in the sound roots, and the yield of tops from 3 sizes of seed in 1959, 1960 and 1961.

Year	Seed Size	Yield of roots tons per acre	Dry matter per cent.	dry matter cwt. per acre	Yield of tops tons per acre
	Large	26.7	12.19	64.6	3.6
1959	Medium	25.3	12.06	60.6	3.7
	Small	24.7	11.83	58.2	3.8
	S.E.	± 0.56	± 0.12	± 0.06	±0.17
	Large	32.5	10.30	66.8	3.3
1960	Graded	31.4	10.20	64.2	3.2
	Small	30.6	10.15	61.6	3.4
	S.E.	± 0.70	± 0.15	± 1.69	±0.17
	Large	37.9	10.77	81.4	4.1
1961	Graded	37.1	10.67	78.4	4.2
	Small	36.2	10.72	77.3	3.9
	S.E.	± 1.27	± 0.18	± 2.06	±0.26
Mean of 3 years	Large	32.4	11.09	70.9	3.7
	Medium	31.3	10.98	67.7	3.7
	Small	30.5	10.90	65.7	3.7

indication that crop yield was affected by differences in population within this range.

In 1960 and 1961, root yields showed a very similar trend to that of 1959, the large seed giving 1.9 tons per acre of roots more than the small seed in 1960, and 1.7 tons per acre more in 1961, while the graded seed was intermediate in yield. The main effects of seed size on the yield of roots and yield of dry matter were non-significant in both years, but the linear component of the seed size effect on the yield of dry matter was significant at the 5% level in 1960.

Averaging the results of the 3 years, the large seed gave 1.9 tons of roots per acre more than the small seed, and 1.1 tons per acre more than the graded seed, equivalent to 4.4 cwt. per acre and 3.2 cwt. per acre of dry matter respectively. When the results of the 3 experiments were analysed as one, the effect of seed size on root yield and dry matter yield was very highly significant (using the seed-size x year interaction as the error term - Table 93 Appendix B). Since the relative yields from the 3 sizes of seed were very similar in each of the years, a small seed-size x year interaction would be expected, but the mean square obtained for this interaction was exceptionally small, being very much smaller than the error mean square. This is a chance effect which is presumably due to the small number of degrees of freedom for the seed-size x year interaction. Although the effect of seed size is almost certainly a significant one, the significance of the effect is, therefore, somewhat exaggerated /

exaggerated. When tested against the error mean square, the effect of seed size on root yield was still significant at the 5% level, while the yield of dry matter just failed to reach significance at the 1% level.

There was no significant difference in the dry matter percentage of the roots from the different seed sizes in any of the years, the mean dry matter percentage of the large, graded and small seed being 11.1, 11.0 and 10.9 respectively.

The yield of tops was also unaffected by the size of the seed, giving on average a yield of 3.7 tons per acre for all sizes of seed.

In the growth studies (Experiment d) carried out primarily to measure leaf areas at various stages of growth, there was no significant difference in the yield of roots or tops, or in the weight of dry matter in the roots and tops of the plants from the different sizes of seed. The standard error for crop yield in this experiment, however, was very high, and the Coefficient of Variation for the weight of roots and weight of tops was 32% and 38% respectively. Details of the plant weights and the statistical analysis are given in Appendix B, Table 166 to Table 173. In the analysis of results, the effect of the date at which plants were removed for leaf area measurements was ignored since the isolated plants were not adjacent to those removed at the various stages. Also, 4 plants were too diseased to be considered in the results, and /

and the total degrees of freedom were, therefore, 49.

In considering the treatment differences in the main experiments in terms of the yield of roots, it is obvious that the differences are relatively much smaller than the differences between the seed weights. Table 24 shows the ratio of graded and small seed weights to the weight of large seed, and the ratio of the root yields from the graded and small seed to the yield from the large seed.

Table 24. The ratio of the seed weights and yield of roots of the small and graded seed to the seed weight and root yield of the large seed.

		Weight of seed per cent.	Yield of roots per cent.
1959	Ratio of graded to large	76.3	94.8
	Ratio of small to large	46.6	92.5
1960	Ratio of graded to large	73.7	96.7
	Ratio of small to large	51.9	94.1
1961	Ratio of graded to large	80.2	97.9
	Ratio of small to large	60.0	95.5
Mean ratio of graded to large		76.7	96.5
Mean ratio of small to large		52.8	94.0

There was no evidence to show that the effect of seed size on root yield differed significantly for the varieties tested, or that the effect of seed size on root yield was influenced by plant spacing /

spacing. Table 25 shows the differences in root yields between the large and graded seed and between the large and small seed, at each population level.

Table 25. Differences in the yield of roots between the large and small seed, and between the large and graded seed, at each plant population level, in 1959 and 1961.

	Yield differences (tons per acre)			
	Plant spacing			
	5 inches	8 inches	11 inches	14 inches
	Large minus small			
1959	-0.14	+1.00	+6.00	+1.11
1961	+1.96	+3.00	-3.52	+5.08
Mean	+0.91	+ 2.00	+ 1.24	+ 3.10
	Large minus graded			
1959	+ 2.04	+0.26	+3.55	-0.31
1961	+ 3.00	+ 2.09	-4.83	+ 2.54
Mean	+ 2.52	+ 1.17	-0.64	+ 1.11

<u>Varieties:</u>

Table 26 gives the yield of roots, yield of dry matter, yield of tops and dry matter percentage for the four varieties in 1960. Victory, Peerless and Superlative are all light purple skinned, early maturing varieties. Best of All belongs to the dark purple skin group and is a late maturing, globe-shaped root, high in dry matter /

matter content.

Table 26. The yield of sound roots, the yield of dry matter in the sound roots, the yield of tops and the dry matter percentage of four swede varieties in 1960.

Variety		Dry Matter	Dry Matter	Tops
	tons per acre	per cent.	cwt. per acre	tons per acre
Victory	34.2	10.12	69.2	3.73
Peerless	32.1	9.57	61.4	2.73
Superlative	30.2	10.19	61.2	2.93
Best of All	29.4	11.03	65.0	3.85
S.E.	± 0.8	± 0.17	± 2.0	± 0.21

The differences in the root and top yields from the four varieties, and differences in the dry matter percentage were significant at the 1% level, while differences in the yield of dry matter were significant at the 5% level. In terms of dry matter yield, Victory was the highest yielding variety being significantly higher than Peerless or Superlative. Best of All gave the lowest yield or roots, but this was offset to some extent by the high dry matter percentage of the roots.

5. Discussion

From the measurement of cotyledon and leaf areas in the growth studies, and from the leaf length measurements and yield estimations in /

in the main experiments, the nature of the growth curves of the swede plants from different sizes of seed, seems fairly clear. The results show that plant weight in the early stages of growth was approximately proportional to the weight of the seed, and that the plants from the different sized seeds maintained the same, or approximately the same, relative growth rate up to around the 30-day stage, after which the relative differences diminished until at maturity the graded seed yielded on average 96.5% of the large seed, and the small seed 94.0% of the large seed. This agrees to a large extent with the results of other workers covering a wide variety of agricultural and horticultural crops, the results varying in detail according to the type of seed, the length of growing season, and the conditions under which the experiments were carried out.

Brenchley (1923) found the Efficiency Index (rate percent. increase per day) fell as the weight of the seed rose, and that this counterbalanced the initial advantage of the large seed with prolonged periods of growth, although with annual crops which were harvested before equilibrium was reached, the advantage was still with the heavier seed. In this respect, the swede may be considered as an annual crop. The work of Kotowski (1925) with cabbage, Fruwirth (1917) with lucerne and sainfoin, and Schmidt (1921) with clover, all lend support to Brenchley's conclusions.

Oexemann (1942) growing soya bean, cucumber, and tomato maintained that although there was little difference in the growth rate /

rate in the first week of growth, there followed a period in which the plants from the small seed grew slower than those from the large seed, and finally, from 7 weeks to maturity, plants from the small seed had a faster rate of growth. He found that the superiority of the large seed gradually diminished, and suggested that if the season were long enough, it would disappear entirely.

Findlay (1919) with swedes, found that there was a marked difference in the size of plants from different sized seeds at brairding, but as the season advanced, the difference grew less, the ratio of small to large seed being 39%, and the corresponding ratio of plant weights at 3 weeks, 7 weeks and 5 months being 48%, 72% and 89% respectively.

Black (1957) studied the effect of seed size on the growth of subterranean clover both in sward and spaced conditions, and concluded that in sward conditions, the factor responsible for the increased relative growth rate from the small seed, and the equation of yields from all sizes of seed, was plant competition. Although the growth of potatoes does not perhaps provide a satisfactory comparison with swedes, it is of interest that Singh (1948) with potatoes, found that the initial advantage inherent in large seed gradually diminished due to the superior assimilation rate of plants from the small seed, and continued to do so until parity was reached. Singh believed that the improved assimilation of plants from small seed was due to less shading and to better resources of light and nutrients available per unit area. In the /

the growth studies in the present series, when plants were isolated some 4 weeks after singling, isolation of the plants was carried out too late to ensure that competition had not occurred, for the leaf length measurements of the main experiment suggests that the growth rate of plants from the large and graded seed had been slowed down relative to those from the small seed, some time before the 4-week stage, either due to competition or some other factor. The results, therefore, probably fail to show the effect of seed size in a non-competitive environment. Fruwirth (1917) working with lucerne and sainfoin, considered the effect of plant spacing on the influence of seed size on plant growth, and found that the superiority of heavy seed was more marked the larger the ground space. The present experiments, however, provide no evidence that plant spacing had any effect on the relative size of plants in the early stages of growth, or the relative weight of the roots at maturity. In the absence of any further information, it is impossible to say whether the reduction in relative weight ratios between sowing and maturity obtained in the main experiments, or in other words, the increase in the efficiency of photosynthesis (Net Assimulation Rate) of the plants from the small seed relative to those from the large seed, is a result of plant competition, or is a natural phenomenon unrelated to competition, as suggested by Brenchley. This is an interesting question from the physiological point of view, but from the practical stand point is probably of little importance. Even if it is assumed that competition /

competition is the causal factor, the widest spacing found in practice could only be expected to delay the effects of competition and the associated reduction in the weight ratios of plants from different sized seeds, and could not be expected to have much effect on yield differences at maturity.

Cummings (1914) working with a large variety of crops obtained the largest treatment differences to be found in the literature. With radish for example, the large seed outyielded the small by 120%. Certainly, this is a short-lived crop, and with Brenchley's (1923) conclusions in mind, large differences in yield might be expected, but Cummings also obtained large yield differences with beans, lettuce, parsley, and spinach. Cummings' work, however, has been severely criticised by Kotowski (1925) on the grounds that not only were seed rates never quoted but that results were upset by differences in plant numbers. With the swede crop, Zavitz (1907) obtained 45% higher yields by using large seed, while Findlay (1919) obtained 11% higher yield as compared to an average of 6% in the present experiments. Seed weights are not quoted by Zavitz, but the difference between the weight of the large and small seed used by Findlay was considerably greater than in the present experiments, the small being 39% of the large as opposed to an average of 55% in the experiments reported here. The only contrary result with swedes is that of Leggatt and Ingalls (1949) who failed to find any difference in root yield at maturity. These experiments, however, two in number /

number, were carried out with rather small numbers of roots, and root yields were likely to have been influenced by the wide variation in root numbers which occurred. On the other hand, it is quite reasonable to expect that in some conditions the initial advantage of the large seed may be lost entirely.

It seems clear that some small yield advantage is likely to be gained by using large seed: the larger the seeds within any variety, the larger is the yield likely to be from them.

The range of seed sizes in swedes varies widely among different varieties, and within one variety varies widely from grower to grower and from year to year. Looking back to Table 12, it can be seen that the lowest percentage of 'rough' seed removed from all the samples used in the experiments, where the tolerance for graded seed was .067 to .077 inches, was 25%. The average was 42%, and the largest amount, in the case of the variety Best of All, was 63%. Again, in examining the percentages of large, graded and small seed obtained in 10 samples of different varieties supplied by a seed firm, it was found that Wilhelmsburger gave 11% rough seed and 69% graded seed. This was the lowest amount of rough seed in the 10 samples examined. The remainder averaged 37% rough seed, and the largest amount (56%) was again taken from Best of All.

The standard of .067 to .077 inches for graded seed has apparently been adopted solely to suit the widest range of samples, and in particular to cater for the variations in seed size which occur /

occur among varieties. Giving consideration to these variations in size which occur, there seems to beevery justification for raising the level at which graded seed is removed from the bulk sample. The degree of tolerance should remain the same, since it has been found adequate for efficient sowing. Raising the level by 20 unit % (representing approximately 16% in terms of numbers of seed) would suit a very wide range of samples, although in all probability the present level would need to be retained for grading any very small-seeded samples, such as these obtained from the variety Wilhelmsburger. The adoption of two standards has obvious disadvantages, but would seem to be the solution to the loss of yield at present being incurred through not using the largest and most productive seed. An increase in root yield of approximately 1 ton per acre (the average difference between the large and graded seed) is worth approximately £2:10. profit (the cost of production) since no additional expense would be incurred. The use of the largest seed with non-precision seeders is also very desirable.

The experiments showed there was a slight advantage in emergence percentage with graded seed, but the average difference between the graded and large seed of nearly 2% is unlikely to outweigh the yielding capacity of the large seed. Furthermore, the graded seed was not superior to the large in emergence percentage for all the varieties tested.

The 1960 experiment showed the importance of variety for

maximum /

maximum yield although choice of variety must also depend on other factors, particularly the time of maturity and the related winter hardiness.

Conclusions:

1. There was no evidence to show that germination percentage or speed of germination is influenced by seed size.

2. The size of the seed can affect its emergence percentage. In the experiments, small seed was inferior to the large and graded seed, while the graded gave a higher emergence percentage than the large seed. The effect of seed size on emergence varies with different varieties or samples, and seems to be dependent on soil conditions. Rate of emergence is unaffected by the size of the seed.

3. In the early stages of growth (up to the 30-day stage approximately) the cotyledon and leaf areas of plants from small seed are smaller than those from larger seed, and the relative growth rates of plants from different sized seeds are approximately equal.

4. After approximately 30 days, plants from small seed grow at a relatively faster rate than those from large seed until at maturity the relative difference in root yield is greatly reduced. There was no evidence to show that the differences in root yield from different sized seeds is influenced by plant spacing.

5. A small advantage in root yield is likely to be gained by using large seed, and the raising of the level at which graded seed is removed from the bulk sample for precision seeding is therefore justified. Where the turnip-barrow is used, the largest seed of the chosen variety should be sown.

D. The Effect of Nitrogen, Phosphorus, and Potassium on Emergence and Seedling Growth, where the Fertiliser is Broadcast before Ridging.

<u>Introduction</u>:

Where precision seeding is practised, a high percentage plant emergence is necessary to ensure a satisfactory plant population level for maximum yields. A poor emergence percentage could be satisfactory where as much as 3 lb. seed per acre is sown with a turnip 'barrow', but could well have a disastrous effect on crop stand where single seeding is practised.

Experiments were carried out from 1959 to 1961 to investigate the effect of 3 levels of nitrogen, phosphorus and potassium on the emergence and growth of the swede seedling when the fertiliser is broadcast before ridging up. This method of fertiliser application, the most widely used in Scotland, may be regarded as semi-placement. In the process of ridging, the fertiliser is squeezed upwards by the ridging bodies, and finishes up in a loose band a few inches below the seed. The extent to which the fertiliser is placed by this operation, appears to depend on the moisture content of the soil. In dry conditions the fertiliser appears to be placed nearer the crown of the ridge than in wet conditions.

<u>Method</u>:

The design used was a 3^3 factorial confounded in 3 blocks of 9 units. One replication was laid down in each of the 3 years.

Treatments /

Treatments were as follows:

nitrogen as sulphate of ammonia lb/acre		phosphorus as superphosphate lb/acre		potassium as muriate of potash lb/acre	
n_o	0	p_o	0	k_o	0
n_1	56	p_1	56	k_1	60
n_2	112	p_2	112	k_2	120

The experiments were laid down on demonstration plots at Bush House. Details of the preceeding crops and previous manuring are given in Appendix A. Table 27 gives the soil analysis for each year.

Table 27. Soil Analyses, 1959-1961.

Year	pH	Available K	Available P
1959	6.2	moderate	moderate-low
1960	6.3	high	moderate-low
1961	6.2	moderate-low	low

Each year the experimental area was ploughed in early spring, then rotavated and harrowed at the end of April. The plots were arranged in 3 banks of 9, each plot being 54 inches wide. Plot length varied in each of the 3 years depending on space available, being 17 feet long in 1959 and 1961 and 21 feet long in 1960.

Fertilisers /

Fertilisers were broadcast by hand and the plots immediately drawn up in 27-inch ridges, two ridges being accommodated exactly within a plot. The ridges were rolled with a diabolo roller. The plots were strung off again leaving 1-yard discard strips at the end of the ridges and between the banks of plots. A known number of seeds per plot were then sown and covered by hand.

Graded Victory seed was used in these experiments. In 1959, 300 seeds were counted and weighed and from this was calculated the weight and number of seed per plot equivalent to 3 lb. per acre, viz. 684 seeds per plot. In 1960, 500 seeds were counted out and weighed and this weight of seed sown per plot. This was approximately equal to 1 seed to the inch. The number of seeds sown in 1959 and 1960 was considered too high to facilitate counting and the number of seeds per plot was reduced to 360 in 1961. After weighing, the seed was dusted with 'Fytolex' against flea beetle attack.

In 1959, the seed was sown on the 14th May in a dry seed bed. This was followed by dry, rather cold weather. No rain fell until the 5th June and the first plants appeared on the 9th June - 26 days after sowing. In 1960, sowing took place on the 7th May when conditions were again very dry, but rain occurred on the 13th May and emergence commenced on the 18th May. The seed was sown on the 4th May in 1961. The seed bed was quite wet, sowing was following by warm sunny weather, and the first signs of emergence occurred on the 11th May.

Plant counts were made at 1- or 2-day intervals until emergence was /

was complete (in about 10 days from the first signs of emergence). A further check count was taken just before singling when plants were singled to 8-inch spacing. Leaf lengths were measured at 2 and 3 weeks after singling, and the procedure adopted was to measure the length of the first foliage leaf of 8 plants selected at random from each of the 27 plots, measuring from the tip of the leaf to the base of the petiole. The number of leaves on each plant was also noted.

The experiments were not carried through to harvest.

<u>Statistical Analysis</u>

Capital letters are used to denote fertiliser main effects and interactions; small letters with the appropriate numeral suffix, to denote treatment levels associated with the different factors.

Two of the degrees of freedom for the second order interaction are confounded. The second order interaction is considered to be negligible, thus the sum of squares corresponding to the 6 degrees of freedom remaining from the second order interaction is used as the error term. Since the effect of the factors is likely to be linear, the only components of the first order interactions likely to be substantial are the interactions of the linear responses to the factors. Three degrees of freedom from each of the first order interactions are, therefore, added to the existing error,,giving a total of 15 degrees of freedom. The sub-division of the degrees of freedom for one replication, where all effects are approximately linear, is as follows:

Blocks /

	degrees of freedom
Blocks	2
Main effects	6
AB (linear x linear)	1
AC (linear x linear)	1
BC (linear x linear)	1
Error	15
Total	26

Where desired, the degree of freedom associated with the linear regression of each of the main effects is isolated.

The linear component, of N and of the interaction NP, for example, is obtained from:

$$N = \frac{N_2 - N_o}{18}$$

$$NP = \frac{N_oP_o + N_2P_2 - N_oP_2 - N_2P_o}{12}$$

Rate Index:

In order to ascertain the effect of treatments on rate of emergence, a Rate Index (Bartlett - 1937) was constructed from the mean fraction of finally emerging seedlings taken over a number of counts, that is

$$\text{Rate Index} = \frac{C_1 + C_2 \ldots\ldots + C_n}{n \times C_n}$$

where

$C_1, C_2 \ldots\ldots C_n$ = the number of plants emerged at the first second .. .. and final counts,

and n = the number of counts made

This /

This index has no absolute meaning, but provides a basis for an efficient analysis of the effect of treatments on the rate of emergence. A high Rate Index indicates a high average plant count (over a number of counts) relative to the final count.

The Rate Index data from the 3 years experiments were analysed together. The mean squares of the interactions N x P x year, N x K x year, and P x K x year were little different from the error mean square, and were included in the error term for testing the first order interactions. The treatment main effects were tested against the treatment x year interaction.

Results:

The effect of the fertiliser levels on the percentage of plants emerged at the first and final counts in each year of trial is given in Table 28 along with the soil analysis of the sites. The results are presented graphically in Figure 6.

Emergence Percentage: Neither phosphorus nor potassium significantly reduced the emergence percentage in any of the years, but it can be seen in Table 28 that the higher level of potassium consistently gave a lower emergence percentage than where no potassium was applied, being on average 2.5% lower over the three years. The effect of potassium was apparently no greater in 1960 when available potassium was high than in 1959 when available potassium was low. In 1959, nitrogen had no significant effect on final emergence, but in 1960 and 1961 the /

Table 28. The response to nitrogen phosphorus and potassium in terms of percentage emergence at the first and final date of counting in 1959, 1960 and 1961, and the soil analysis of the site.

Treatment	Year	Percentage emergence - first count 0	Response to 1	Response to 2	Percentage emergence - final count 0	Response to 1	Response to 2	Soil Analysis
	59	12.2	-1.5	-3.3	45.9	-2.9	-0.8	
Nitrogen	60	38.7	-3.8	-8.7	75.4	-1.0	-6.3	
	61	50.2	-5.9	-5.1	84.1	-2.7	-4.6	
	Mean	33.7	-3.7	-5.7	68.5	-2.2	-3.9	
	59	9.2	1.9	1.7	46.5	-0.8	-3.8	Moderate
Phosphorus	60	32.3	6.8	-0.2	71.3	4.4	3.5	Moderate low
	61	47.0	0.5	-1.9	81.4	1.9	-0.2	Low
	Mean	29.5	3.1	-0.1	66.4	1.8	-0.2	
	59	11.3	-0.7	-1.5	46.5	-0.7	-3.9	Low
Potassium	60	30.0	7.0	6.8	73.8	1.5	-1.9	High
	61	43.3	5.6	4.5	83.3	-3.2	-1.7	Moderate low
	Mean	28.2	4.0	3.3	67.9	-0.8	-2.5	

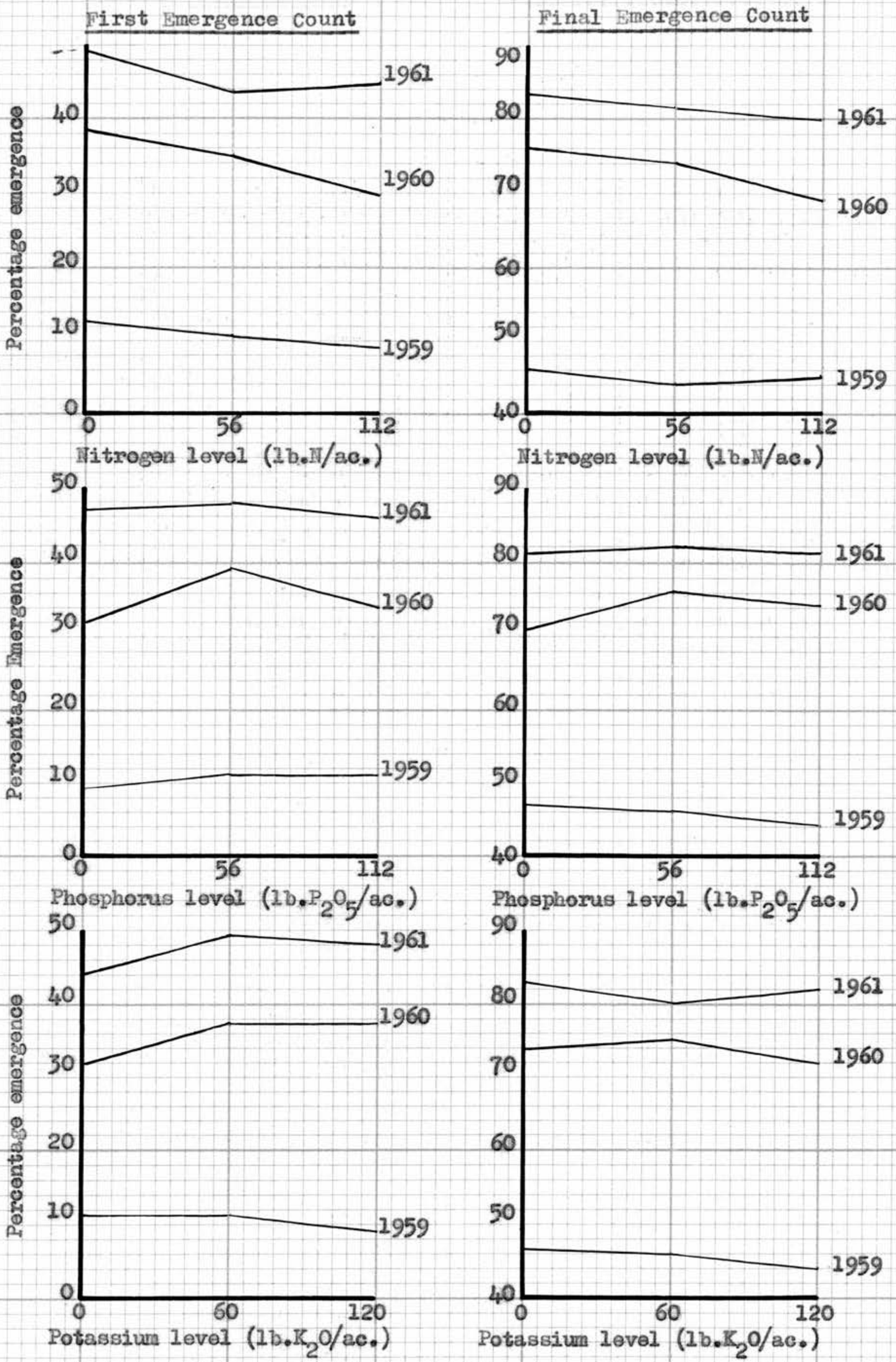


Figure 6. The effect of nitrogen, phosphorus and potassium on the percentage of plants emerged at the first and final counts in 1959, 1960 and 1961.

the effect of nitrogen was linear and significant at the 5% level. Averaged over the 3 years, 56 lb. nitrogen reduced emergence by 2.2%, and 112 lb. nitrogen reduced it by 3.9%. None of the treatment interactions was significant.

Emergence at the first count: Phosphorus had no significant effect on emergence at the first count in any of the years. The main effect of potassium was also non-significant in each year, but in 1961, K_o was significantly lower than the average of K_1 and K_2 ($P = .05$). In 1960, a similar tendency failed to reach significance. Averaged over the 3 years, emergence at the first count was 4 unit % higher where 60 lb. K_2O per acre was applied, and 3.3 unit % higher where 120 lb. K_2O was applied. 56 lb. nitrogen reduced the percentage of emerged plants at the first count by 3.7%, and 112 lb. nitrogen by 5.7% when averaged over the 3 years. The effect of nitrogen was significant in 1961 ($P = .05$). In 1959, the effect of nitrogen was linear, being significant at the 5% level, and in 1960 the linear effect just failed to reach significance ($VR = 4.21$; $F_{.05} = 4.54$) when emergence at the higher level of nitrogen was 8.7 unit % lower than the 'no nitrogen' treatment. None of the treatment interactions was significant.

Rate of emergence: The effect of nitrogen, phosphorus and potassium on the number of plants emerged at each count, averaged over the 3 years, is shown in Figure 7, Figure 8 and Figure 9 respectively, and the mean Rate Index /

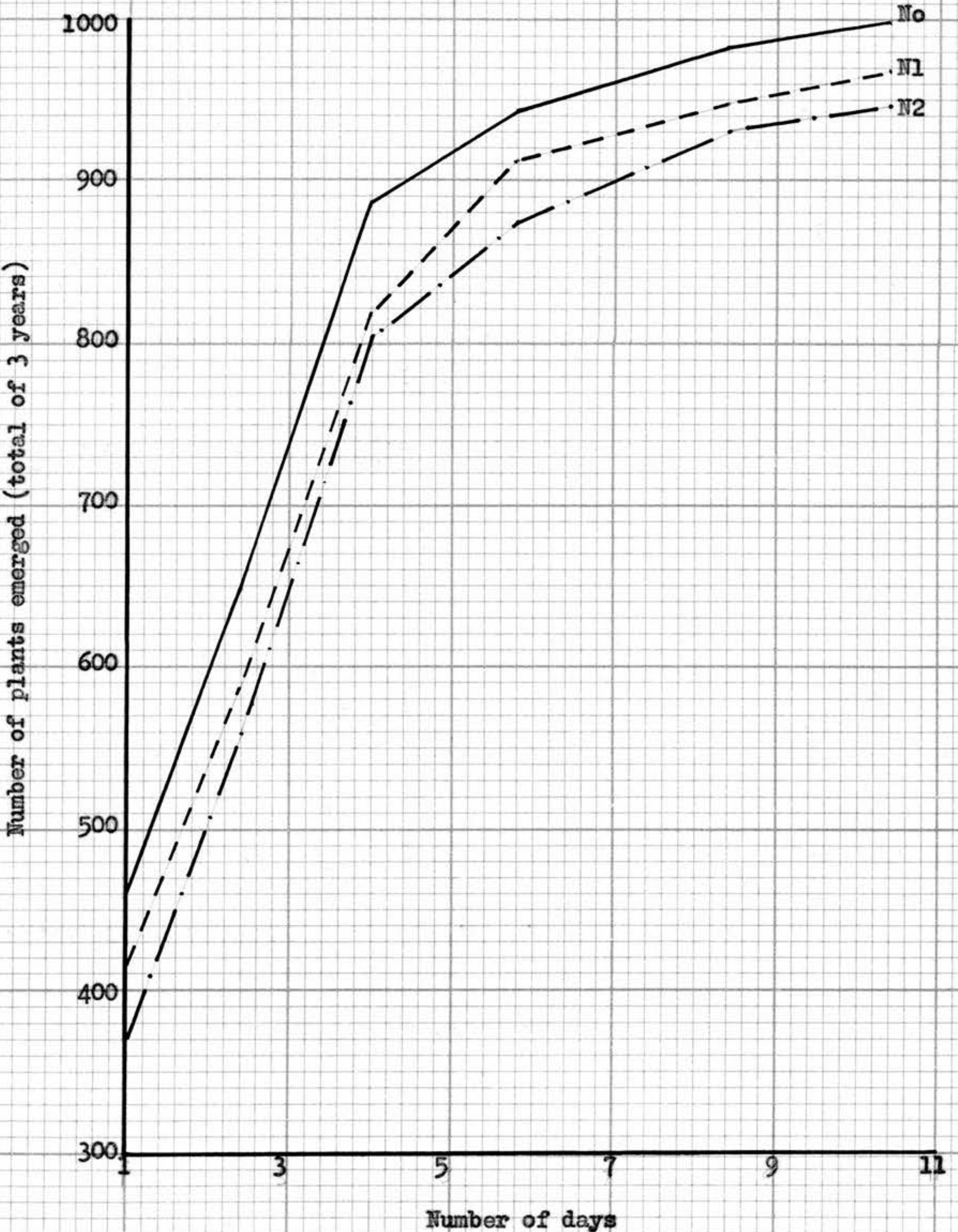


Figure 7. The effect of nitrogen on the number of plants emerged per day, 1959-61.

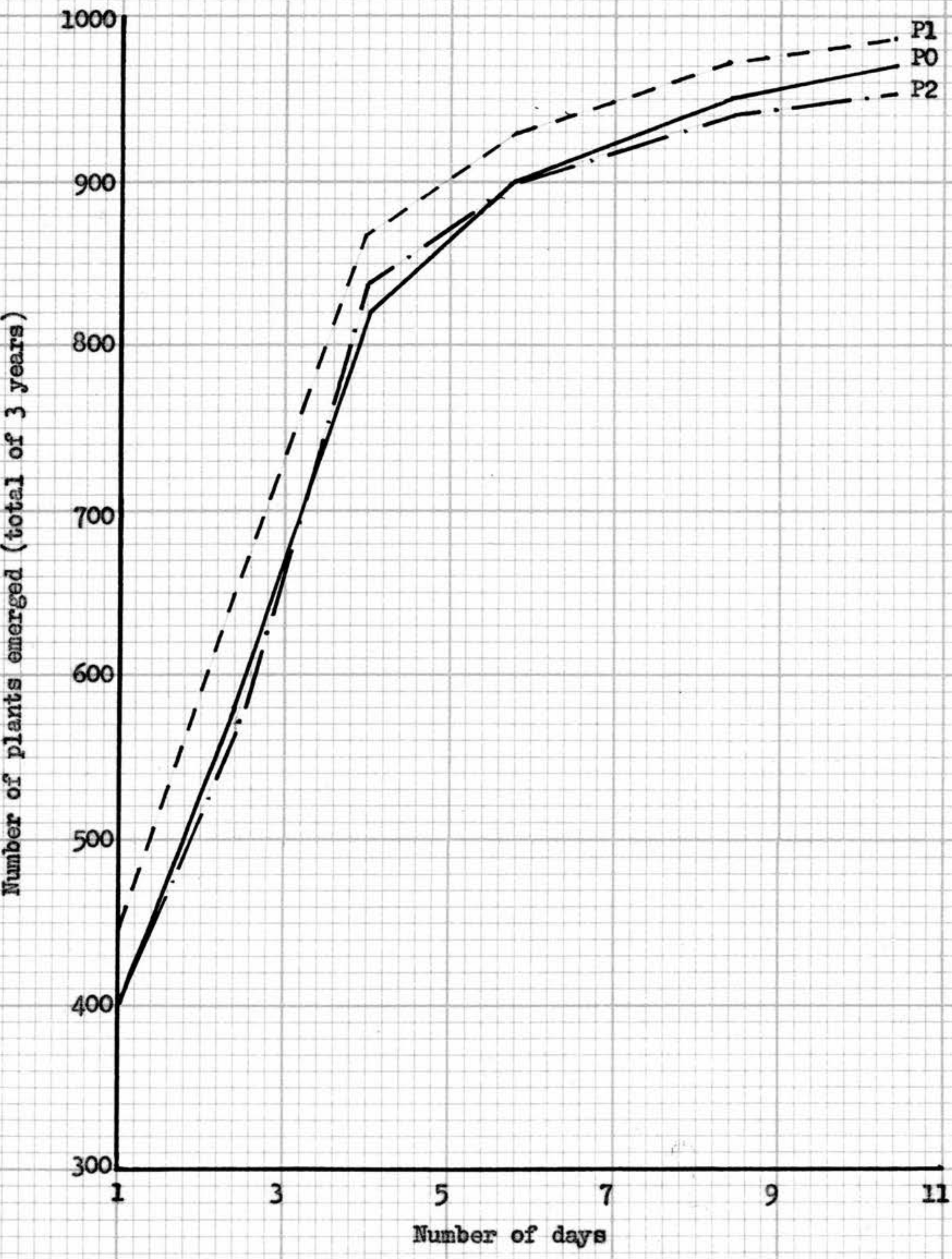


Figure 8. The effect of phosphorus on the number of plants emerged per day, 1959-1961.

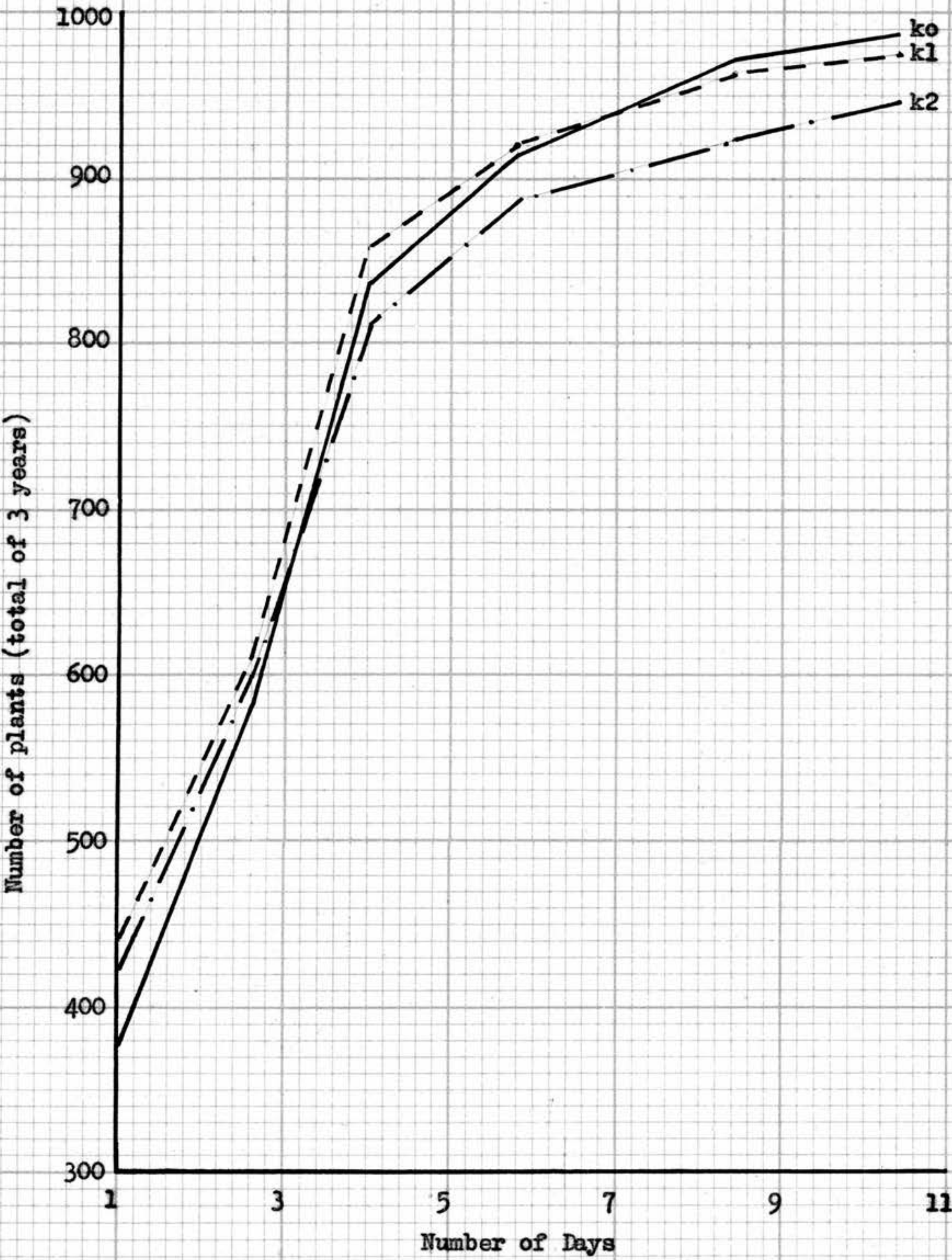


Figure 9. The effect of potassium on the number of plants emerged per day, 1959-1961.

Index for each treatment level is given in Table 29.

Table 29. The mean Rate Index at each level of nitrogen, phosphorus and potassium in 1959, 1960 and 1961.

Level	Treatment		
	N	P	K
0	.807	.777	.772
1	.780	.800	.796
2	.773	.783	.792
		S.E. = ± .006	

Testing the treatment main effects against the treatment x year interaction, the effect of nitrogen was significant at the 1% level. Since the nitrogen x year interaction was smaller than the pooled error mean square, the nitrogen effect was also tested against the pooled error and was still significant at the 1% level. When the first order interactions were tested against the pooled error, the nitrogen x potassium (linear x linear) interaction was significant at the 5% level. None of the other main effects or interactions was significant. The nitrogen x potassium two-way table is given below.

Table 30. The mean Rate Index, 1959 to 1961 - nitrogen x potassium.

	N_0	n_1	n_2	
k_0	.797	.776	.743	
k_1	.825	.781	.782	S.E. = ± .010
k_2	.800	.782	.792	

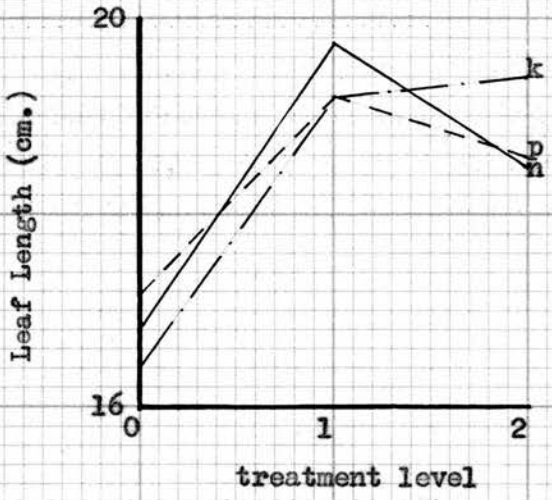
The /

The Rate Index was reduced by increasing levels of nitrogen, but this was offset to a large extent by the effect of potassium.

In interpreting the results of the Rate Index analysis, it must be borne in mind that the Rate Index compares mean plant counts (over a number of counts) in relation to the final count, and not the increase in the number of plants per day.

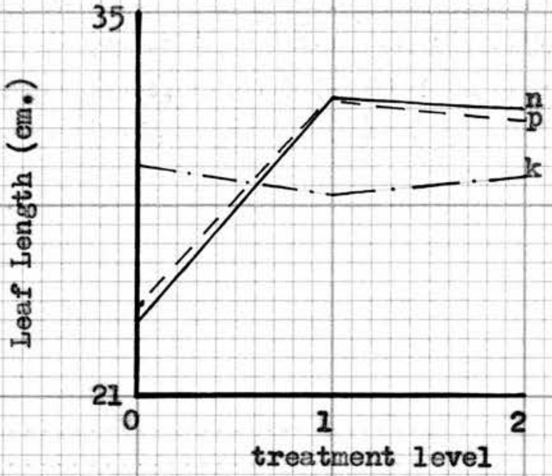
Growth and development: In none of the years was there any visible harmful effects of the fertilisers on plant growth. There was also no evidence of plants dying off, and check counts taken immediately before singling gave the same number of plants as at the last emergence count. There was a marked visible response to nitrogen in each of the years.

These observations on plant growth are supported by the statistical analysis of the leaf length data. Figure 10 shows the effect of nitrogen, phosphorus and potassium on the length of the first foliage leaf when measured 3 weeks after singling. The length of the leaves was significantly increased 3 weeks after singling in 1959 by 56 lb. nitrogen, and 60 lb. potassium ($P = .05$), but there was no additional response to either nitrogen or potassium at the higher level of application. The effect of phosphorus was non-significant. In 1960, none of the treatments increased leaf length 2 weeks after singling, but at 3 weeks, there was a significant response to nitrogen and phosphorus ($P = .05$) at the lower level of application, but no additional response to the higher levels. The effect of potassium was non-significant. In 1961, at both 2 and 3 weeks after singling, there /



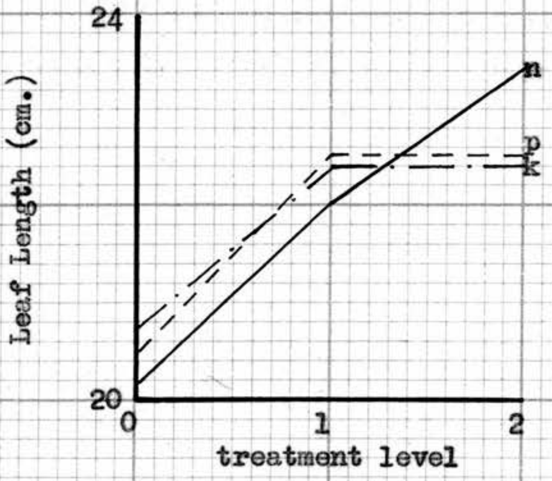
1959

low available potassium
moderate available phosphorus.



1960

high available potassium
moderate low available phosphorus.



1961

moderate low available potassium
low available phosphorus.

Figure 10. The effect of nitrogen, phosphorus and potassium on the length of the first foliage leaf when measured 3 weeks after singling, 1959-1961, along with the soil analysis of the site.

there was significant response to nitrogen (P = .01), phosphorus and potassium (P = .05), all responses being to the lower levels of application only, except for nitrogen at the 3-week stage, when the effect was linear.

At the 3-week stage each year, the nitrogen x phosphorus (linear x linear) interaction was significant at the 5% level. This interaction was positive in 1959 and 1961, but negative in 1960. The nitrogen x phosphorus two-way tables are presented below. In 1959 and 1961, there was no response to nitrogen alone or phosphorus alone, but a significant response to nitrogen where phosphorus was applied. In 1960, there was a response to nitrogen alone, and a similar response to phosphorus alone, but no additional response to nitrogen or phosphorus when applied together. Whether or not there was a response to nitrogen in the presence of applied phosphorus, was not associated with the level of available phosphorus as indicated by soil analysis.

Table 31 /

Table 31. The mean length of the first foliage leaf 3 weeks after singling in 1959, 1960 and 1961. - nitrogen x phosphorus.

		n_0	n_1	n_2	
	p_0	17.5	17.7	16.5	
1959	p_1	18.4	20.7	18.5	S.E. = ± 1.16
	p_2	14.5	20.7	20.5	
	p_0	18.7	22.7	24.2	
1960	p_1	23.1	25.2	24.1	S.E. = ± 1.10
	p_2	23.6	24.5	23.8	
	p_0	20.4	20.9	20.3	
1961	p_1	19.7	23.1	24.5	S.E. = ± 0.91
	p_2	20.3	21.9	25.4	

A count of the number of leaves per plant was taken only in 1960 and 1961. In 1960, and 2 weeks after singling in 1961, none of the treatments significantly affected the number of leaves per plant, but 3 weeks after singling in 1961, the number of leaves was significantly increased by nitrogen and phosphorus ($P = .05$) and the linear component of the potassium effects was also significant at the 5%.level. The effect of the treatment on the number of leaves per plant in 1961 is shown in Table 32.

Table 32 /

Table 32. The mean number of leaves per plant at each level of nitrogen, phosphorus and potassium, 3 weeks after singling in 1961.

Level	Treatment n	p	k	
0	11.0	11.1	11.2	
1	11.9	11.8	11.7	S.E. = $\pm$0.22
2	12.0	12.0	12.0	

Discussion:

Superphosphate and muriate of potash:

The results showed that at the various levels of available phosphorus and potassium encountered at the 3 sites, where superphosphate up to the level of 112 lb. P_2O_5 per acre, and muriate of potash up to the level of 120 lb. K_2O per acre were broadcast before ridging, there was little danger of serious damage to emergence. However, the consistently negative response to the higher level of potassium suggested that the maximum amount of muriate of potash for safe emergence had been reached. These results are in agreement with those of Reith (1959). Growing swedes on the ridge in low phosphate soils, Reith found that emergence was unaffected by superphosphate up to 80 lb. P_2O_5 per acre, and muriate of potash up to 120 lb. K_2O per acre whatever the method of application.

Several workers have drawn attention to the fact that the harmful effects of placed fertiliser are greatest where the available /

available soil nutrient level is high (Lewis - 1941, Reith - 1959, Hanley - 1947). In none of the sites in the present series of experiments, was available phosphate high, but it is interesting to note that the effect of potassium on emergence was no greater in 1960 when the level of available potassium was high than in 1959 when available potassium was low.

Although the effect of superphosphate was non-significant either on the emergence percentage or Rate Index, a study of Figure 8 does suggest that the lower level of superphosphate may have assisted plant establishment at emergence, but the effect, if any, is a very small one. The response to superphosphate in terms of leaf size in 1960 and in 1961, and the increase in leaf numbers in 1961 shows that superphosphate broadcast before ridging is readily available to plants at an early stage, and can assist the growth and development of the seedling where available phosphorus is low or moderately low. In 1959 when available phosphorus was moderate - the highest level of the 3 sites - there was no response to superphosphate.

The results with muriate of potash were similar to those with superphosphate. The leaf length data showed that in 1959 and 1961 when available potassium was low, muriate of potash assisted plant growth and development, but had no effect on plant growth in 1960 when available potassium was high (Figure 10).

<u>Sulphate of ammonia:</u>

The results show that broadcasting sulphate of ammonia before ridging /

ridging, does present some risk of damage to emergence.

There were very considerable differences from year to year in the soil moisture content at emergence - very dry in 1959, fairly dry in 1960 and moist in 1961. In 1959 when emergence was obviously restricted by lack of moisture and the mean emergence percentage was 44.7 compared to 73.0 in 1960, and 81.7 in 1961, the reduction in emergence percentage due to sulphate of ammonia was half of what it was in the two following years. Several workers (Hanley - 1957, Reith - 1951, Cooke -1949, Hudson - 1928) have pointed out that damage to emergence is greatest when the soil moisture content is low. In the present case, it can only be postulated that in 1959 the soil moisture level was too low to dissolve the sulphate of ammonia in amounts sufficient to cause serious plasmolysis; in 1960 and 1961 the soil moisture content was sufficient to create a soil solution strong enough to plasmolyse the seed, thereby reducing the emergence percentage. This is supported by the work of Olsen and Drier (1956) with oats.

In considering the significant effects of sulphate of ammonia on the Rate Index, it must be remembered that the Rate Index is used to compare the mean plant count in relation to the final count, and it can be seen in Figure 7, since the graphs are virtually parallel, that after the initial effect of the sulphate of ammonia on the seed, emergence at each level of sulphate of ammonia proceeded at approximately the same rate (increase in the number of plants per

day /

day). It would appear that the fertiliser destroys the germinating capacity of some seeds, probably those nearest to the dissolving fertiliser particles, and the remaining seed germinates and emergences at a rate (increase in the number of plants per day) little affected by the level of fertiliser. The differences in emergence rate indicated by analysis of the Rate Index only reflect, therefore, the effect of the sulphate of ammonia on the emergence percentage. The significant nitrogen x potassium interaction obtained on analysis of the Rate Index reflects the high emergence percentage produced by the muriate of potash at the start of emergence, offsetting to some extent the adverse effect of the sulphate of ammonia.

Although the sulphate of ammonia was detrimental to plant emergence, the results showed that each year, the fertiliser assisted the growth and development of the seedling at an early stage, and that even with high levels of sulphate of ammonia (112 lb. nitrogen) there was no evidence of scorching the seedlings. The significant nitrogen x phosphorus interactions for leaf length however show that growth response of the seedling to sulphate of ammonia is dependent on the level of applied or available phosphorus.

In the experiments, 56 lb. nitrogen, which is equivalent in nitrogen supplied, to 8 cwt. of a 6 : 15 : 15 compound, reduced emergence by approximately 2% on average, the maximum reduction produced by this level of nitrogen being nearly 3%. Applications of fertiliser much in excess of this are rarely encountered in practice /

practice, and a reduction in emergence of the nature of 3% is likely to have little effect on plant stand even when the crop is precision sown - certainly not to the extent that yield would be affected. This finds support to some extent in the work of Reith (1959) who found that broadcasting sulphate of ammonia at a rate equivalent to 40 lb. nitrogen per acre had no effect on plant stand: only placement below the seed produced any harmful effects. It is conceivable, however, that when sulphate of ammonia is applied much in excess of this level, emergence may be reduced sufficiently to affect yield, particularly if the crop is precision sown at very wide intervals. In 1960, 112 lb. nitrogen reduced emergence by 6% and this reduction could perhaps be exceeded where conditions for plasmolysis were optimal.

Since there were no significant two-factor interactions in the analysis of the final emergence count, there is no evidence that the effect of any two of the fertilisers is other than additive. Little information on the three-factor interaction can be obtained, since this largely constitutes the error term, and it is of little value to compare the sum of the individual effects of the fertilisers at one level with the effect of the three fertilisers applied together (at the same level), since individual plots would be compared. It is reasonable to assume, however, that the main effects of the three fertilisers are at least additive. Summing the effects of the three fertilisers at the highest level (averaged for the three years), the reduction in emergence percentage was 6.6%. 8 cwt. per acre of a 6 : 15: 15 compound is approximately /

approximately equivalent, in nutrients supplied, to the lower level of nitrogen used in the experiments, and the higher levels of phosphorus and potassium. The reduction in emergence percentage with these levels of the fertilisers could be expected to be around 5%, which present some risk to emergence, and possibly plant stand.

There is no reason to suppose that the effect of nutrients supplied by compound granual fertilisers would have a more harmful effect on emergence than mixtures of single nutrient fertilisers, since the release of nutrients into the soil from a granular fertiliser is somewhat slower than that from a non-granular one. The compound may have less effect on emergence than the single nutrient fertilisers, weight for weight of plant nutrients, since the total amount of soluble salts may be lower.

Conclusions:

Where fertilisers are broadcast immediately before ridging, the following conclusions may be drawn:

(1) In soils where available phosphorus is low or moderate , phosphorus up to the equivalent of 112 lb. P_2O_5 per acre can be applied with little risk of damage to emergence.

(2) The upper limit of applied potassium for safe emergence appears to lie a little below the equivalent of 120 lb. K_2O per acre.

(3) Some damage to emergence can be expected when the equivalent of 56 lb. nitrogen per acre is applied, but damage at this level is likely to be small and have little effect on plant stand /

stand: where nitrogen is applied much in excess of recommended levels more serious damage to emergence is likely to occur.

(4) The effect of nitrogen, phosphorus and potassium on emergence is likely to be additive and a reduction in emergence percentage of around 5% can be expected with a dressing of 8 cwt. per acre of a compound fertiliser.

(5) The fertilisers are placed where they are readily available to the seedling, and moderate levels of phosphorus and potassium can be expected to assist plant growth and development where the available soil nutrients are low or moderately-low. Applications of nitrogen can also assist plant growth, but the response to nitrogen is dependent on the level of available or applied phosphorus.

E. The Effect on Crop Yield of Weeds Growing Between the Plants, and the Removal of the Weeds at Different Stages of Crop Plant Growth.

Introduction:

The high labour demands which characterise modern farming are most serious in connection with row-crop cultivation. It is useful, therefore, to investigate the effect of weeds growing between the plants, (weeds which are normally controlled by hand hoeing), the stage of crop plant growth at which weeds are most harmful to crop yield, and the reduction in yield that might occur as a result of omitting some of the cleaning operations associated with traditional husbandry.

Several workers have studied the effect of removing weeds at different stages of crop growth. Russell (1947) stated that in general, field experiments have shown that weeds were more harmful in the young crop than when it was well established. Shadbolt and Holm (1956) working with carrot and red beet, and Bleasdale (1959) with onion and red beet, drew similar conclusions.

In recent years, crops of swedes have been grown by precision seeding at intervals so wide that singling could be omitted entirely. The effect of leaving inter-plant weeds untouched, where inter-row cultivations are proceeding normally, was therefore investigated.

Method:

The design chosen was a balanced one of 3 replications of a

4^2 /

4^2 factorial confounded in blocks of 4 units (Cochrane and Cox - 1955). Plant population was the second factor investigated.

Treatments were:

Weeding

A - Inter-plant weeds removed at singling and kept clean.

B - Inter-plant weeds removed at A + approximately 2 weeks, and kept clean.

C - Inter-plant weeds removed at A + approximately 4 weeks, and kept clean.

D - Inter-plant weeds left untouched.

Plant spacing:

1 - 5 inch spacing

2 - 8 inch spacing

3 - 11 inch spacing

4 - 14 inch spacing

Details of the preceeding crop, fertiliser application and soil analysis are given in Appendix A.

The seed was precision sown at $1\frac{1}{4}$-inch spacing on 27-inch ridges. The variety Victory was used in 1959 and 1960, and Broadland in 1961. Before singling, the drills were scarified, and the plots were measured out and marked off with twine, each plot measuring 4 drills x 10 yards long -approximately 1/160 acre. Plants were singled by hand to the required spacings at the 3-rough leaf stage, and a count was made of the number of remaining plants. A single inter-row hoeing was given between /

between 2 and 3 weeks after singling.

In treatment A, weeds and unwanted seedlings were removed by hand. In treatments B and D, singling was carried out by carefully picking unwanted plants and leaving the weeds between the singled plants. An additional treatment (Z) was included in each sub-block in 1960 and 1961. This plot received similar treatment to A in the sub-block except that the soil around the seedling was removed at singling exposing the hypocotyl, that is, the seedling was 'couped'. In the A, B, C and D treatments the soil around the plants was disturbed as little as possible.

Conditions in 1959 were very dry from sowing time on the 30th April, and at singling time (4th to 7th June) there were very few weeds growing in the crop. The weed species present in greatest amount were sorrel, day nettle, chickweed and charlock. Also present were couch grass and annual meadow grass. Crop growth was very slow at this stage, and the weeds in the B plots were not removed until the 23rd June, when the plants had grown about 6 foliage leaves. The A plots were cleaned again at the same time, and 2 weeks later on the 7th July, when the plants had reached the 10-leaf stage, the C plots were weeded, and the A and B plots, which showed very little regrowth of weeds were cleaned once more. At this stage, chickweed was the most obvious species in the unweeded plots. On the whole, however, the crop could be considered a fairly clean one.

In 1960, the seed was sown on the 23rd May. The dry pre-

sowing /

sowing conditions continued until after brairding but from brairding onwards there was no shortage of moisture and the crop grew quickly. Singling was carried out on the 9th and 10th June. As in 1959, the whole trial area was fairly clean at this stage. The weed species present were redshank, charlock, fat hen, chickweed and some annual meadow-grass. The B plots were weeded on the 24th June when the swede plants had grown between 6 and 8 foliage leaves and the weed population had increased considerably. The A plots were reweeded the following day. On the 9th July the C plots were weeded and the A and B plots were cleaned again. There was little regrowth of weeds in the A and B plots but where weeds had been left untouched as in the C and D treatments, weed growth was considerable.

The spring and early summer of 1961 was characterised by cold, dry and windy weather. The seed was sown on the 12th May in a good tilth and fairly moist warm conditions. The cold dry spell which followed retarded emergence and when brairding commenced at the end of May, it was very uneven. Singling was started on the 14th June, but some parts of the experimental area were not ready for singling until 23rd June. The trial was located partly on the lower end of a slope and partly on level ground below the slope. The upper part of the trial grew slowly and was not too seriously troubled by weeds, whereas the lower part grew quickly and soon become very dirty with chickweed and charlock. Other weed species present were fumitory, fat hen, and knot-grass. The B plots were weeded on the 5th July,

the /

the C plots on the 19th July, and any regrowth of weeds in those plots already weeded, cleaned away. As in the two previous years, there was little regrowth of weeds, but the unweeded plots on the lower part of the trial were quite rank with chickweed and charlock, while the upper part of the trial was less severely infested by weeds, though still quite dirty.

In 1959, the dry weather at sowing continued until September. The crop became severely mildewed in August, and by mid-September, the plants had little foliage although some regrowth occurred later. The trial was harvested in mid-November and gave an average yield of 26.1 tons per acre. The moist summer and autumn of 1960 produced a good crop of roots. The trial was harvested during the last week of November and gave on average 43.3 tons per acre. In 1961, after the crop recovered from the cold dry conditions which persisted into July, it made good growth in the wetter summer months and when harvested at the end of November, yielded on average 39.0 tons per acre.

Before harvesting, an estimation was made of the erectness of growth habit of the plants in each plot. The method employed for this and the effect of couping the seedling, both on growth habit and crop yield will be discussed along with the results of an experiment specially designed to investigate this effect, (Section F).

Statistical Analysis

Each replicate confounds completely a set of 3 of the 9 degrees /

degrees of freedom for the weeding x plant spacing interaction. The relative information on the interaction is therefore 2/3.

To compute the sum of squares for AB, let B_{mn} be the total of the nth block in the mth replicate, and let T_{mn} be the total of all treatments that appear in this block.

Let $P_{mn} = T_{mn} - B_{mn}$. Then,

$$AB = 1/8\ (P_{11}{}^2 + P_{12}{}^2 + \ldots P_{34}{}^2) - 1/32(G^2 + R_1{}^2 + R_{11}{}^2 + R_{111}{}^2)$$

where G is the grand total and the R's are replication totals.

The estimated block mean (adjusted for treatment effects) is:

$$b_{mn} = \frac{3B_{mn} - T_{mn}}{8}$$

To present a two-way table, the adjusted mean of treatmentAA1 is, for example,

$$A1' = A1 - 1/3(b_{1b} + b_{11a} + b_{111b})$$

where this treatment occurs in 1b, 11a, and 111b.

Estimated gain in precision from confounding: The advantage to be obtained by confounding lies in the amount the experimental error is decreased by reducing the block size. An estimate E_r is made of the experimental error which would have been obtained had the experiment been a randomized block. This is directly compared with the estimated error from the confounded design.

Assuming that the confounded comparisons are negligible,

$$E_r = \frac{n_b E_b + N_e E_e}{n_b + n_e}$$

where /

where,

E_b = mean square for blocks within replicates.

E_e = error mean square.

n_b = number of degrees of freedom for blocks within replicates.

n_e = total number of degrees of freedom minus the number of degrees of freedom for replicates minus n_b.

Results:

Crop Yield: Details of the root and top yields from the weeding treatments in each of the 3 years is given in Table 33. Where weeds were allowed to grow for only 2 weeks after singling, there was no significant loss of yield. Where weeds remained for 4 weeks after singling, the yield of roots was, on average, 1.2 tons per acre lower than where weeds were removed when singling. This effect was non-significant in each experiment.

In 1959 where no inter-plant cultivations were carried out, there was a significant reduction in yield (compared to treatment A) of 1.9 tons of roots per acre ($P = .01$). In 1960, neither the yield of roots nor the yield of dry matter from the roots was significantly affected by the continued growth of weeds, but again in 1961, allowing the weeds to grow unchecked significantly reduced the yield of roots by 5.0 tons per acre ($P = .05$).

The dry matter percentage of the roots was not significantly affected /

Table 33. The yield of sound roots, the dry matter percentage of the roots, the yield of dry matter from the sound roots, and the yield of tops from the weeding treatments in 1959, 1960 and 1961.

Year	Weeding treatment	Yield of roots tons per acre	Dry matter per cent.	Yield of dry matter cwt. per acre	Yield of tops tons per acre
1959	Weeded at singling	26.7	10.91	58.1	3.8
	Weeded 2 weeks after singling	27.0	10.94	59.1	3.8
	Weeded 4 weeks after singling	26.0	11.07	57.5	4.0
	Unweeded	24.8	10.91	54.1	3.8
	S.E.	± 0.42	± 0.10	± 0.72	±0.11
1960	Weeded at singling	43.4	9.40	81.6	6.3
	Weeded 2 weeks after singling	43.5	9.62	83.7	6.2
	Weeded 4 weeks after singling	42.5	9.58	81.2	6.4
	Unweeded	43.4	9.61	83.4	6.6
	S.E.	± 0.60	± 0.09	± 1.20	±0.23
1961	Weeded at singling	39.9	9.77	77.9	3.5
	Weeded 2 weeks after singling	40.1	9.65	77.3	3.9
	Weeded 4 weeks after singling	38.3	9.54	73.7	3.8
	Unweeded	34.9	10.07	70.2	3.9
	S.E.	± 0.65	± 0.14	± 1.73	±0.27
Mean 1959-61	Weeded at singling	36.7	10.03	72.5	4.5
	Weeded 2 weeks after singling	36.9	10.07	73.4	4.6
	Weeded 4 weeks after singling	35.5	10.06	70.8	4.7
	Unweeded	34.4	10.20	69.2	4.7

affected by any of the weeding treatments in any of the experiments.

The weeding x spacing interaction for the yield of roots was significant at the 5% level in 1960, but non-significant in 1959 and 1961, and the same interaction for the yield of dry matter just reached significance in 1959. The two-way tables for the significant interactions are shown below, (Tables 34 and 35).

Table 34 suggests that weeds reduced crop yield at the widest spacing but not at the narrower spacings. The significance of the interaction, however, should be treated with some caution, for the two-way table is difficult to interpret. Firstly, the yield of unweeded plots at 5-inch and 8-inch spacing was higher than at the same spacings where weeds were removed at singling, and secondly, the yield of roots from the plots singled to 14-inch spacing and weeded 4 weeks after singling, was lower than for any of the other 'weeding' treatments, including the unweeded plots. The factor chiefly responsible for this low yield was the large number of diseased roots harvested from this treatment (Appendix B, Table 237).

In Table 35, it can be seen that at 5-, 8-, and 11- inch spacing, the unchecked growth of weeds reduced the yield of dry matter, but at 14- inch spacing the yield of dry matter was 1.2 cwt. per acre of dry matter higher than for the plots weeded at singling. The reduction in the yield of roots due to treatment D (unweeded) at the four plant spacings in each of the experiments is shown in Table 36.

Table 36 /

Table 34. The mean yield of sound roots, 1960 - weeding x spacing (adjusted).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
	tons per acre	tons per acre	tons per acre	tons per acre	
5-inch spacing	43.9	42.2	43.8	44.6	
8-inch spacing	43.9	43.0	43.1	46.0	S.E. = $\pm$1.08
11-inch spacing	40.5	46.5	44.1	41.6	
14-inch spacing	45.5	42.3	38.1	41.5	

Table 35. The mean yield of dry matter from the sound roots, 1959 weeding x spacing (adjusted).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
	cwt. per acre	cwt. per acre	cwt. per acre	cwt. per acre	
5-inch spacing	58.0	60.9	55.6	54.9	
8-inch spacing	59.0	60.9	59.6	48.7	S.E. = $\pm$1.44
11-inch spacing	61.5	59.2	55.9	57.6	
14-inch spacing	53.9	54.9	58.7	55.1	

Table 36. The mean effect of weeds (treatment D) on the yield of sound roots at 5-, 8-, 11- and 14- inch plant spacings in 1959, 1960 and 1961.

	cwt. per acre			
	1959	1960	1961	Mean
5-inch spacing	-19.8	36.0	- 43.1	- 9.0
8-inch spacing	-79.9	21.6	-108.5	-55.6
11-inch spacing	-48.9	0.8	-149.2	-65.8
14-inch spacing	9.9	-57.2	- 65.2	-28.1

The 'mean' column does suggest that yield losses due to weeds were less at very close spacing than at wider spacings, but in view of the criticisms of Table 34 and the contradictory results in 1959, the evidence is not strong enough to draw any definite conclusion.

The yield of tops was not significantly affected by the growth of weeds in any of the years, and none of the weeding x spacing interactions for the yield of tops was significant.

<u>The number of plants remaining after singling and the number of roots harvested</u>: Details of plant numbers after singling and before harvest are given in Table 37. None of the weeding treatments significantly affected the number of plants remaining after singling, the number of sound roots, or the mortality rate.

<u>Disease</u>: There was a tendency for disease incidence to be lower where weeds were allowed to grow unchecked compared to where weeds were cleaned /

Table 37. The number of plants remaining after singling, the number of sound roots harvested, and the mortality rate for the weeding treatments in 1959, 1960 and 1961.

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	S.E.
	Post-singling plant count (plants per acre).				
1959	24,602	24,857	25,205	24,723	±386
1960	24,750	26,197	26,050	26,050	±451
1961	27,068	27,189	27,470	27,644	±483
Mean	25,473	26,081	26,242	26,277	
	Number of sound roots harvested (roots per acre).				
1959	21,989	23,249	23,195	23,356	±419
1960	21,185	22,432	22,338	22,633	±467
1961	26,197	25,272	25,299	26,117	±435
Mean	23,124	23,651	23,611	24,035	
	Mortality rate (per cent.).				
1959	5.8	4.1	5.6	4.0	±1.5
1960	11.2	9.1	10.3	11.1	±1.5
1961	2.7	5.9	5.9	4.1	±1.5
Mean	6.6	6.4	7.3	6.4	

cleaned away in the course of singling. The number and weight of diseased roots for the weeding treatments in 1959 and 1960 is given in Table 38. Since only 18 diseased roots were harvested from the whole trial area in 1961, no information on disease incidence can be obtained from the results of that year. The unweeded plots produced approximately 1/3 of the weight of diseased roots of those plots weeded at singling. The effect of the weeding treatments on the number of diseased roots was highly significant in 1959 (chi^2 = 31.2 with 3 d.f.) and significant at the 6% level in 1960 (chi^2 = 7.75 with 3 d.f.). The weeding treatments also significantly affected the weight of diseased roots in 1959 ($P = .05$) but this effect just failed to reach significance in 1960 (V.R. = 3.04; $F_{.05}$ = 3.47).

Table 38. The number of weight of diseased roots harvested from each of the weeding treatments in 1959 and 1960.

	Weeded at singling		Weeded 2 weeks after singling		Weeded 4 weeks after singling		Unweeded	
Year	Number roots per acre	Weight cwt. per aacre	Number roots per acfe	Weight cwt. per acre	Number roots per acre	Weight cwt. per acre	Number roots per acre	Weight cwt. per acre
1959	697	24.2	308	8.0	375	16.0	147	6.1
1960	590	30.5	509	25.1	683	31.2	362	15.2
Mean	643	27.3	408	16.5	529	23.6	254	10.7

The weed growth possibly provided some protection against the spread of /

of disease. It has been shown that the incidence of dry and bacterial rots is lower when plants are closely spaced (Levy - 1923, Neil - 1929, Whitehead - 1935), and it has been suggested that the denser leaf cover which closely spaced plants provide, inhibits the spread of disease by splashing rain. The weed growth may have had a similar effect to higher plant density. This is discussed further in the population studies in Section G.

Gain in precision by confounding:

The estimated gain in precision by confounding was calculated for the weight of roots in each of the experiments as shown on page 129. The estimated gain in precision over a randomized block design was 37% in 1959, 22% in 1960, and 9% in 1961.

Discussion:

Russell (1947) stated that there were three main sources of competition between weeds and crop plants, namely, nutrients, soil moisture and light. In view of the soil analysis results and the levels of fertiliser and dung which were applied in this series of experiments, nutrients are assumed to be present in adequate quantities, and since shading of the crop plants by the weeds did not occur to any extent, and is unlikely to do so in the swede crop unless weeds are very profuse in the early stages, soil moisture would appear to be the factor most likely to limit crop growth as a result of competition with weeds.

The effect of weeds in the 3 experiments, that is, the extent

to

to which yield was reduced by allowing inter-plant weeds to grow unchecked throughout the growing season, is, therefore, considered from the point of view of weed intensity and rainfall - Table 39. The measure of weed intensity was purely a visual one and was a measure of the average ground cover throughout the trial area. Weed counts are of little value in considering the effect of weeds on crop yield. Shadbolt and Holm (1956) pointed out that,in time, a relatively sparse weed population will produce as much weedy material as will a much heavier stand. The rainfall considered was that between singling and the end of August, by which time it was assumed the weed population would have no effect on crop yield. The average rainfall for this period over the years 1951 to 1961 was 9.31 inches.

In 1959 when rainfall was low - less than half the 1951 - 1961 average, a weed infestation developing in intensity from very light to moderate, reduced the yield of roots by 1.9 tons per acre. A similar weed infestation with almost twice the amount of rainfall in 1960 failed to reduce the yield of roots, while a moderate to heavy weed infestation in 1961, even with substantial rainfall, reduced yield by 5 tons per acre.

Table 39 /

Table 39. The loss in yield due to the unchecked growth of inter-plant weeds (treatment A minus treatment D), the rainfall between singling and the end of August, and the estimated weed intensity at singling, and 4 weeks after singling.

Year	Loss in yield A - D tons per acre	Rainfall Singling - end August inches	Estimated weed intensity at singling	Estimated weed intensity of unweeded plots, 4 weeks after singling
1959	1.9	4.49	very light	moderate
1960	0.0	8.36	very light	moderate
1961	5.0	7.38	moderate	heavy

It can be postulated that, in conditions of high fertility at least, where inter-plant weeds are of light to moderate intensity, and the weeds are allowed to grow unchecked, yield losses are likely to occur when rainfall is low, but that little or no reduction in yield is likely where rainfall is adequate; where weeds are present in moderate to heavy intensity, considerable yield reductions are likely to occur even when rainfall is not far below average. Russell (1942) concluded from his experiments at Rothamsted and Woburn, that if nutrients or moisture were in short supply, quite modest weed competition could adversely affect the growth of young sugar beet plants and their ultimate yield, and that if nutrients were present in adequate amounts, the crop could tolerate considerable weed infestation without any effect on yield.

Although /

Although rainfall and weed intensity seem likely to have been the chief causes of differences in the extent to which yields were reduced from year to year, the weed species present would also have some effect. The most obvious difference in this respect was the very strong growth of charlock in 1961 when this weed pervaded the crop into August, and was probably chiefly responsible for the large loss in yield.

Weeds growing between the plants from singling until approximately 2 weeks later did not reduce crop yield in any of the years. There was also no significant reduction in yield when weeds were allowed to grow for 4 weeks after singling, but this treatment gave a lower yield of roots than those plots weeded at singling or 2 weeks after singling in every experiment. On average, the removal of weeds after singling gave 1.2 tons per acre of roots less than where weeds were removed when singling. It does appear, therefore, that some loss in yield was incurred by weeds growing in the crop from the second to the fourth week after singling. A further average loss in yield of 1.1 tons per acre was obtained where inter-plant weed growth was untouched.

These results agree to some extent with the work of Bleasdale (1959) who found that delaying the first weeding could reduce crop yield, so there was presumably a period in the very early stages of the crop when weeds had little influence. Similarly, Shadbolt and Holm (1956) found that with carrots, weeds growing in the crop for

3½ /

$3\frac{1}{2}$ weeks had little effect on crop yield, but after $4\frac{1}{2}$ weeks yield was significantly reduced, further though smaller reductions occurring when weeds remained in the crop for $5\frac{1}{2}$ weeks. With red beet, however, the crop completely recovered from the effect of weeds in the early stages. In the present experiments, although no yield losses occurred when weeds were left growing in the crop during the first 2 weeks after singling, this period was a critical one from the point of view of weed 'build-up' and by 2 to 4 weeks after singling, weed intensity had increased sufficiently to cause loss in yield. It is assumed that there was a similar occurrence in the experiments carried out by Bleasdale (1959) and Shadbolt and Holm (1956). It would appear that the period of maximum weed influence depends not only on the stage of crop growth, but on the stage at which weed intensity becomes sufficient to interfere with growth.

Russell (1947) stated that field experiments have shown in general that weeds were more harmful in the young crop than when it was well established, and obtained yield increases of between 2 and 3 tons per acre of sugar beet where an additional hoeing was carried out in the young crop. Shadbolt and Holm (1956) and Bleasdale (1959 and 1960) also concluded that weeds were more harmful in the early stages of growth. In all these experiments, however, at least one weeding was carried out and none of the experiments gave any indication of the effect of weeds had they been allowed to remain in the crop throughout the growing season. In none of the experiments in the present /

present series was weed intensity at singling at all severe and when weeds were cleared away at singling there was never any significant renewal of weed growth in the ensuing 2-week period, so presumably no loss in yield due to the regrowth of weeds would have occurred in those plots weeded at some stage. The experiments have shown, however, that once weed intensity has been allowed to build up in a crop, the influence of weeds, as determined by loss of yield at maturity, can continue for as long as four or more weeks after singling, despite the shading which must occur from the crop plants. The loss of yield due to weeds in the crop at a fairly advanced stage of growth can be much greater than that at an early stage. In 1961, the loss in yield due to weeds growing in the crop from 4 weeks after singling onwards was 3.4 tons per acre, while weeds growing in the crop between 2 and 4 weeks after singling reduced the yield by 1.6 tons per acre. Weeds in the crop up to 2 weeks after singling did not affect crop yield.

In the past few years there have been claims of satisfactory crops grown by precision seeding at wide intervals and not singled, but it can only be wondered how much better those crops might have been had they been hoed in the traditional manner. Maddox (1958) in four trials, obtained no loss in yield through not singling, but stressed that in all cases the fields were fairly clean and free from weeds. Edmunds (1959) obtained similar results in Wales, and the experiments in the present series also show that losses may not necessarily be incurred where hand hoeing is omitted. On the other /

other hand, a loss of 5 tons of roots per acre was incurred by moderate to heavy weed infestation, and it is quite probable that higher yield losses may occur where fertility and rainfall are low. A loss of 5 tons per acre represents a loss of approximately £14 per acre, and against this is set the cost of singling. Robertson (1959) found that a crop precision seeded at 2-inch spacing could be singled at the rate of $\frac{3}{4}$ mile per hour. In practice, a figure of $\frac{1}{2}$ mile per hour might be more realistic, and at this rate, the cost of singling is approximately £1:15s. per acre. It is clear, therefore, that the growing of root crops without inter-plant hoeing cannot be recommended as a practice, for apart from loss in yield, the spread of weed seed from a fairly light weed population could well outweigh the beneficial effects of a weed control programme in previous years. Nevertheless, where crops are precision sown at wide intervals in conditions of good fertility and adequate rainfall, and where weed intensity is light when plants have reached the singling stage, little loss in yield might be expected if hoeing were omitted. Under these conditions, the method may be regarded as a useful alternative to traditional husbandry in the event of labour shortage, or excessive demands on existing labour. The omission of inter-plant hoeing is likely to be most successful where the swede crop is taken after a ley when the crop is usually much cleaner.

<u>Conclusions:</u>

In /

In conditions of high fertility the following conclusions may be drawn:

(1) Where weeds are allowed to grow between the plants until 2 weeks after singling there is little likelyhood of yield losses, but a small yield reduction is likely where the weed growth continues 4 weeks after singling.

(2) Where inter-plant weeds grow unchecked, yield losses are likely to occur, although there may be no loss of yield where weed intensity is low and rainfall plentiful. Unchecked weed growth may be even more harmful to the crop at an advanced stage of growth than in the early stages.

(3) There was little evidence to suggest that the effect on root yield of weeds growing between the plants, is influenced by plant spacing.

F. The Effect of Exposing the Hypocotyl when Singling, and the Effect of the Method of Sowing.

Introduction:

(a) Couping

Since it has been common practice for many years to intentionally coup the swede seedling when singling, it is useful to investigate the effect of couping on crop yield, and to establish at which stage of growth the plant is most susceptible to damage, if any, by couping. With the introduction of mechanical harvesting, the erectness of a crop has become important. It is also useful therefore to study the effect of couping the seedling on the growth habit of the mature roots.

In a series of experiments with swedes to find out if late singling reduced the yield of roots more when the crop was sown with the turnip barrow than if precision sown, Holmes and Lang (unpublished) found that in 4 trials out of 6, the barrow-sown swedes gave a significantly lower yield than those precision sown at 2-inch spacing (averaged for all stages of singling). It was considered that a possible explanation for this might be found in the singling operation. Where the plants were growing thickly together, much of the soil around the plants was moved in the course of singling, and the plants left in a lax position with the hypocotyl well exposed, whereas when spaced 2 or 4 inches apart, the plants and even the soil immediately surrounding them were often untouched by the hoe in the course of singling /

singling.

(b) Method of sowing.

Robertson (1959) emphasized the importance of a good seed bed and evenly contoured ridges for accurate seeding, and described a roller seed unit which was useful for this operation. On this machine, notched drill rollers of heavy casting are mounted in a floating position in front of the seeder units. Robertson found this arrangement gave a useful compacting action, broke up clods, was heavy enough to push down stones which tended to lift lighter diabolo rollers, and left a smooth even ridge which was of considerable assistance to efficient mechanical thinning.

The additional rolling described above might, it was thought, produce plants more erect in growth, by giving some support to the seedling, and making them less easy to coup when singling. Three methods of sowing were therefore studied, namely, sowing with the turnip barrow, precision sowing with plain diabolo rollers and precision sowing with the roller seed unit described above, followed by a further rolling with the notched rollers alone (the seeder units being raised out of work).

With the mechanisation of seeding increasing steadily, various types of precision seeder are now available, and these are described briefly by Robertson (1959). The seeder used in the experiments was a four-unit Stanhay precision seeder in which the sowing mechanism is a revolving flat rubber belt in which holes are punched to allow seeds /

seeds to be sown at the required intervals.

Method:

1960: In 1960, a randomized block design consisting of 4 replications of a 2^2 x 3 factorial was laid down. The treatments were:-

Method of Sowing:

T - Sown with the turnip 'barrow' at 3 lb. per acre.

P - Precision sown at $1\frac{1}{2}$ - inch spacing, with plain diabolo rollers in front of the seeder units.

R - Precision sown at $1\frac{1}{2}$ -inch spacing, rolling before and after sowing with a notched drill roller.

Method of Singling:

E - Singled by hand - the soil around the plant being cleared away to expose the hypocotyl, and so couping the plant.

C - Singled by hand - the soil around the plant being undisturbed and the plant left erect.

Stage of Singling:

I - Singled when plants had on average 2 - 3 foliage leaves.

2 - Singled when plants had on average 5 - 6 foliage leaves.

Plots were 20 yards long x 2 drills wide, equal to 1/160 acre.

1961: In 1961, a split-plot design was used. The 3 methods of sowing studied in 1960 were main plot treatments. An additional singling method to those studied in 1960 was introduced (H = singling with a hoe) and the sub-plots were a 3 x 2 factorial of the 3 singling /

singling methods and 2 stages of singling. This design was replicated 4 times. Plots were 10 yards long x 4 drills wide, equal to 1/160 acre. The soil analysis, preceeding crop, and fertiliser application for both experiments are given in Appendix A.

In 1960, the trial area was ploughed during the first week of December, and disced and rolled twice at the end of April. The ground dried out rather quickly during cultivations with the result that the seed was sown on the 11th May in a dry coarse seed bed. The sowing depth for the different sowing methods was kept as uniform as possible. Brairding commenced on the 24th May, but those drills precision sown and rolled with the notched roller were a day or two later to braird, and for all treatments the braird was uneven. The drills were scarified on the 6th June and the first singling done on the 13th June when the plants had on average grown 3 foliage leaves. The second singling was done on the 21st June when the plants had on average 6 foliage leaves. The plants were singled to 12-inch spacing by hand, using a stick cut to the correct length.

In 1961, the trial area was ploughed at the beginning of December and a fine tilth obtained by discing and harrowing on the 10th May. The area was ridged up and the seed sown in very good conditions on the 11th May. Sowing was followed by cold, dry, rather windy weather, and the first signs of emergence occurred on 19th May, but then only on those drills precision sown and unrolled. This was followed 2 days later by the turnip-barrow sown swedes, but the drills /

drills precision sown and rolled with the notched roller did not braird until the 6th June. Emergence and subsequent growth, particularly where additional rolling was done, were both slow and uneven, so that singling could not be done in clearly defined stages. The drills were scarified on the 21st June and a start to singling was made on the 22nd June. All plots were considered individually and were singled when the average stage of development of the plants in the plot reached the 3 rough-leaf, or 6 rough-leaf stage, according to treatment. The precision sown and rolled plots were singled several days later than the other sowing methods, and singling was not completed until the 10th July. The plants were singled accurately to 9-inch spacing along the rows.

In both experiments, an estimate of the plant density from each sowing method, was made before singling by counting all plants along 4 single yard lengths of drill - 2 one - yard lengths from each of the 2 drills in 1960, and 1 one - yard length from each of the 4 drills in 1961. The yard lengths of drill were chosen at random in the drill by throwing down a cane 1 yard long.

A post-singling count was also carried out in both experiments, all plants in each plot being counted. In 1960, this was done immediately after each singling stage, but in 1961 was not done until all singling had been completed, 18 days after singling commenced.

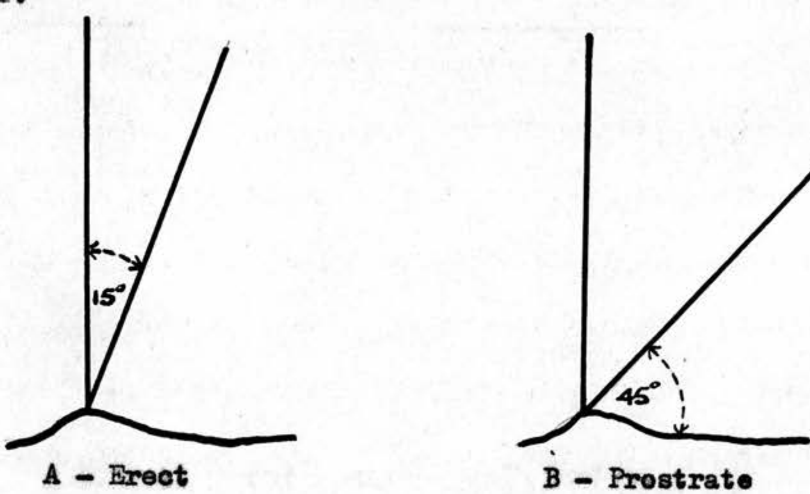
Before harvesting the experiments, an assessment of the

erectness /

erectness of all plants in each plot was made. The method employed is described below.

In 1960, the experiment was harvested during the third week of December and yielded on average 39.0 tons per acre; the 1961 experiment was harvested during the second week of December, and yielded on average 36.1 tons per acre.

Assessment of growth habit: The erectness of the bulb growth was assessed by eye. A count was taken of the number of roots in each plot estimated to come into each of the classifications shown in Figure 11.



A - The vertical axis of the root, vertical, or within 15 degrees of the vertical.

B - The vertical axis of the root more than 45 degrees from the vertical.

Figure 11. Growth habit classifications.

Results:

Before /

Before considering the results of the experiments described above, the results of Section E will be dealt with: the couped and uncouped plots (all of them weeded at singling) are compared.

(a) <u>Section E. A comparison of the couped and uncouped plots.</u>

Only in 1960 was there any visible effect of couping, other than the effect on growth habit. In this experiment, the couped plants did not appear to make as much growth as the uncouped ones for about four weeks after singling.

<u>Crop yield and plant numbers</u>: The effect of exposing the hypocotyl at singling on the yield of roots and tops, and the effect on plant numbers is shown in Table 40 and Table 41, respectively. Couping the plants at singling significantly reduced the yield of roots by 2.7 tons per acre in 1960, equivalent to 5.0 cwt. of dry matter, while in 1961, although the effect of couping failed to reach significance (V.R. = 3.03; $F_{.05}$ = 4.60), the yield of the couped plants was 1.5 tons per acre lower than the uncouped ones, equivalent to 3.4 cwt. per acre of dry matter.

At first glance, the percentage mortality in 1960 suggests that the couped plants were no less able to survive the singling period than those left erect at singling, but the post-singling plant count in this instance was not carried out until 18 days after singling, when the number of couped plants was significantly lower than the uncouped ones ($P = .05$). This effect is reflected in the number of sound roots harvested although the difference in plant numbers at harvest was not significant. On analysis of covariance (Table 42) in /

Table 40. The effect of exposing the hypocotyl at singling on the yield of sound roots, the yield of dry matter in the sound roots, and the yield of tops, in 1960 and 1961 (Section E).

Method of singling	Yield of roots			Yield of dry matter			Yield of tops		
	tons per acre			cwt. per acre			tons per acre		
	1960	1961	Mean	1960	1961	Mean	1960	1961	Mean
Uncouped	43.4	39.9	41.7	81.6	77.9	79.7	6.29	3.53	4.91
Couped	40.7	38.4	39.5	76.6	74.5	75.5	6.13	3.50	4.81
S.E.	± 0.47	± 0.58		± 1.00	± 1.73		±0.20	±0.20	

Table 41. The effect of exposing the hypocotyl at singling on the post-singling plant count, the number of sound roots harvested and the percentage mortality in 1960 and 1961 (Section E).

Method of Singling	Post-singling plant count		Number of sound roots harvested		Mortality	
	plants per acre		roots per acre		per cent.	
	1960	1961	1960	1961	1960	1961
Uncouped	24,750	27,068	21,185	26,197	11.2	2.5
Couped	23,437	26,317	20,395	24,133	10.3	6.7
S.E.	± 322	± 371	± 435	± 531	± 1.0	±1.5

Table 42 /

Table 42. Covariance analysis: the number of plants (x) and the yield of roots (y) in 1960 (Section E)

Source	d.f.	S.S. and S.P.			Errors of Estimate			V.R.
		x^2	xy	y^2	S.S.	D.F.	M.S.	
Total	23	46619	7156	31072				
Replicates	2	78	- 697	6424				
Spacing (S)	3	45153	6138	3069				
Couping (C)	1	400	1838	8438				
S x C	3	331	- 205	5797				
Error	14	657	82	7344	7334	13	564	
Error + C	15	1057	1920	15782	12294	14		
Difference for testing adjusted means					4960	1	4960	8.79*

Table 43. Covariance analysis: the number of roots (x) and the yield of roots (y) in 1961 (Section E).

Source	d.f.	S.S. and S.P.			Errors of Estimate			V.R.
		x^2	xy	y^2	S.S.	D.F.	M.S.	
Total	23	79296	3852.8	24855.99				
Replicates	2	1077	421.7	5504.02				
Spacing (S)	3	75148	813.0	3854.94				
Couping (C)	1	988	1536.8	2390.01				
S x C	3	251	- 515.2	2081.87				
Error	14	1832	1596.5	11025.15	9633.8	13	741.1	
Error + C	15	2820	3133.3	13415.16	9933.8	14		
Difference for testing adjusted means					300.0	1	300.0	0.40

in which the yield of roots was adjusted for differences in the number of plants remaining after singling, the variance ratio was reduced from 16.10** to 8.19* which suggests that part at least of the treatment difference in 1960 may have been due to a difference in plant numbers. Since any effect of plant losses on the yield of roots would be felt most at wide spacing, the probability that plant numbers affected the yield of the couped plants is supported by the significant couping x spacing interaction (P = .05) for the yield of roots; couping reduced the yield of roots at the widest spacing (14,500 plants per acre) by 6.3 tons per acre, while the mean loss in yield at the three closer spacings was 1.4 tons per acre. The two-way table is shown below.

Table 44. The effect of couping on the yield of roots at 5-, 8-, 11-, and 14- inch spacing in 1960.

	tons per acre		
	Uncouped	Couped	
5-inch spacing	43.4	41.9	
8-inch spacing	43.9	41.7	S.E. = $\pm$0.94
11-inch spacing	41.0	40.5	
14-inch spacing	45.4	39.1	

The 14-inch spacing gave populations of 15,143 plants per acre for the uncouped plants, and 13,908 plants per acre for the couped ones, and while the population studies (Section G) showed no loss in /

in yield at low population over the range of populations studied, 13,908 plants per acre is slightly below this level, so that some loss in yield due to lack of plant numbers could have been incurred, particularly where gaps occurred in the plant spacing due to irregular braird.

In 1961 when the post-singling count was made the day after singling was complete, singling being spread over a period of 10 days, plant numbers were not significantly different, but at harvest the couped plants had approximately 2000 plants per acre fewer than those uncouped, the percentage mortality being 2.5 and 6.7 respectively. This effect of the method of singling on the number of roots harvested was significant at the 5% level. Covariance analysis (Table 43) in which the yield of roots was adjusted for differences in plant numbers, reduced the variance ratio from 3.03 to .40, showing an association between low yield and loss of plant numbers, but in view of the population studies (Section G) it is unlikely that the slightly lower yield of roots from the couped plants was due to loss of plants, since at 14-inch spacing the number of roots from the couped and uncouped plots was 16,003 per acre and 16,540 per acre. The population studies showed no loss in the total yield of roots at populations considerably below this.

None of the couping x spacing interactions for the yield of roots or yield of dry matter was significant, and the yield of tops was not significantly affected by couping in either of the experiments. The dry /

dry matter percentage in the roots was also not significantly affected by couping, but in 1961 the couping x spacing interaction for the dry matter percentage of the roots was just significant at the 5% level (Appendix B, Table 248). This can only be interpreted as a chance effect, the dry matter percentage of the uncouped plants at 8-inch spacing being higher than for any of the other spacings, while the dry matter percentage of the couped plants at 8-inch spacing was lower than for any other treatment.

<u>Growth habit</u>: The percentage of plants growing erect and 'prostrate' is given in Table 45.

Table 45. The effect of couping on growth habit in 1960 and 1961 (Section E).

Year	Percentage Prostrate			Percentage Erect		
	Uncouped	Couped	Mean	Uncouped	Couped	Mean
1960	34	61	48	20	5	12
1961	4	16	10	45	21	33

Couping the plants at singling produced a much greater number of plants growing in a prostrate position and fewer plants growing erect than where the plants were left upright at singling. The treatment effects, both for the percentage of plants growing erect and prostrate, were significant at the 1% level. Although couping was done in exactly the same manner each year, the 1961 crop, on average /

average, grew much more erect; on average 48% of the plants were growing in the prostrate position in 1960 as opposed to only 12% in 1961.

Disease: The amount of disease in the 1961 crop was negligible, and the results in 1960 give no reason to believe that plants couped at singling are more susceptible to disease than those left upright. In 1960, the couped plants gave 590 diseased roots per acre weighing 15.3 cwt., and the uncouped, 563 diseased roots per acre weighing 14.4 cwt.

(b) Section F.

(i) The effect of exposing the hypocotyl at singling.

Crop yield and plant numbers: The effect of the method of singling on crop yield and plant numbers in 1960 and 1961 is shown in Table 46 and Table 47 respectively. In 1960 the couped plants yielded 1.2 tons per acre of roots less than the uncouped plants, but this effect was non-significant. In the following year there was virtually no difference in the yield of roots or the yield of dry matter between the couped and uncouped plots, but singling by hoe significantly reduced the yield of roots by 1.5 tons per acre or 3.2 cwt. per acre of dry matter ($P = .05$).

Couping did not significantly affect the numbers of roots at harvest in 1960, but in 1961, singling by hoe gave a significantly lower number of plants 18 days after singling than the hand-singled treatments ($P = .01$) and fewer roots at harvest ($P = .05$). When the yield /

Table 46. The effect of the method of singling on the yield of sound roots, the yield of dry matter in the sound roots, and the yield of tops in 1960 and 1961.

Method of Singling	Yield of roots tons per acre			Yield of dry matter cwt. per acre			Yield of tops tons per acre		
	1960	1961	Mean	1960	1961	Mean	1960	1961	Mean
Uncouped	39.6	36.5	38.1	76.6	70.2	73.4	3.58	3.84	3.71
Couped	38.4	36.7	37.5	74.0	70.6	72.3	3.74	3.85	3.79
Singled by hoe	-	35.0	-	-	67.2	-	-	3.76	-
S.E.	± 0.49	± 0.42		± 1.00	± 1.00		±0.10	±0.11	

Table 47. The effect of the method of singling on the post-singing plant count, the number of roots harvested and the percentage mortality in 1960 and 1961.

Method of singling	Post-singling plant count Plants per acre		Number of sound roots harvested roots per acre		Mortality per cent.	
	1960	1961	1960	1961	1960	1961
Uncouped	18,458	25,386	16,582	24,227	6.6	4.6
Couped	19,163	24,354	16,984	23,262	7.8	4.6
Singled by hoe	-	22,619	-	21,661	-	4.7
S.E.	± 242	± 258	± 269	± 237	±0.5	±0.6

yield of roots in 1961 was adjusted for differences in root numbers by covariance analysis (Table 48), the main effects were still significant though only at the 5% level, showing some association of yield losses due to hoeing and loss in plant numbers. It seems unlikely that this loss in yield was a result of low population since the population studies (Section G) showed no losses in yield at populations of 15,000 plants per acre with similar root yields. There was no significant difference in mortality rate between the different methods of singling in either of the years.

Stage of singling: The effect of the stage of singling on the crop yield and plant numbers is shown in Tables 50 and 51 respectively. The later singled plants in 1960 significantly outyielded the earlier singled ones by 1.5 tons per acre (P = .05), and also gave a significantly higher plant count after singling and more roots at harvest (P = .01). On analysis of covariance (Table 49) in which the root yield was adjusted for differences in plant numbers, the variance ratio was reduced from 5.17* to 0.51 showing a considerable degree of association of the two factors. The population studies (Section G) would suggest that at this population level (the early singling gave 16,240 roots per acre and the later singling 17,326 roots per acre) no loss in yield would occur due to lack of plant numbers, but quite considerable gaps occurred in this experiment due to the dry rough tilth, and it is conceivable that loss of plants was partly responsible for the low yield at the earlier stage of singling.

Early /

Table 48. Covariance analysis: the number of roots (x) and the yield (y) in 1961 (Section F).

Source	d.f.	S.S. and S.P.			Errors of Estimate			V.R.
		x^2	xy	y^2	S.S.	D.F.	M.S.	
Total	41	8880	-3406.9	146104.9				
Main plots	11	1238	-3324.9	83052.5				
Stage of singling (S)	1	1395	-3236.1	7503.2				
Method of singling (C)	2	3118	+4526.8	8393.2				
S x C	2	399	- 822.7	2280.2				
S x M	2	168	+ 22.3	2206.7				
M x C	4	139	+ 546.9	4153.8				
S x M x C	4	90	- 317.4	2438.4				
Error (b)	45	2333	- 801.8	36076.9	35801.3	44	813.7	
Error + C	47	5451	3725.0	44470.1	41924.6	46		
Difference for testing adjusted means					6123.3	2	3061.6	3.76*

Table 49 /

Table 49. Covariance analysis: the number of roots (x) and the yield of roots (y) in 1960 (Section F).

Source	d.f.	S.S. and S.P.			Errors of Estimate			V.R.
		x^2	xy	y^2	S.S.	D.F.	M.S.	
Total	47	6319	12750	81352				
Replicates	3	874	1120	7437				
Stage of singling (S)	1	784	2522	8112				
Method of sowing (M)	2	1108	1161	3003				
Method of singling (C)	1	108	- 714	4721				
S x M	2	115	572	2856				
M x C	2	31	2	1098				
S x C	1	1	44	1496				
S x M x C	2	67	- 54	808				
Error	33	3231	8097	51821	31350	32	980	
Error + S	34	4015	10619	59933	31848	33		
Difference for testing adjusted means					498	1	498	0.51
Error + M		4339	9258	54824	35071	34		
Difference for testing adjusted means					3721	2	1860	1.90

Table 50. The effect of the stage of singling on the yield of sound roots, the yield of dry matter in the sound roots, and the yield of tops in 1960 and 1961.

Stage of singling	Yield of roots tons per acre			Yield of dry matter cwt. per acre			Yield of tops tons per acre		
	1960	1961	Mean	1960	1961	Mean	1960	1961	Mean
2-3 foliage leaves	38.2	36.2	37.5	74.2	70.9	72.5	3.65	3.83	3.74
5-6 foliage leaves	39.7	35.4	37.5	76.4	67.8	72.1	3.67	3.80	3.73
S.E.	± 0.49	± 0.38		± 1.00	± 0.80		±0.10	±0.09	

Table 51. The effect of the stage of singling on the post-singling plant count, and the number of sound roots harvested in 1960 and 1961.

Stage of singling	Post-singling plant count plants per acre		Number of sound roots harvested roots per acre	
	1960	1961	1960	1961
2-3 foliage leaves	18,211	23,539	16,240	22,359
5-6 foliage leaves	19,410	24,701	17,326	23,776
S.E.	± 242	± 150	± 269	± 193

Early singling outyielded the later singling in 1961 by 1.4 tons of roots per acre, the effect of the stage of singling on root yield and yield of dry matter being significant at the 1% level. The stage of singling also affected the number of roots harvested, the earlier singling being significantly lower than the later singling ($P = .01$). Since the highest yielding treatment produced the fewest roots, covariance was deemed unnecessary.

Neither the method of singling nor the stage of singling significantly affected the dry matter percentage of the roots or the yield of tops.

<u>The effect of stage of singling on the method of singling</u>: None of the interactions in 1960 or 1961 were significant for the yield of roots or the yield of dry matter, but the method of singling x stage of singling interaction for the number of plants remaining after singling, and the number of sound roots harvested, was significant in 1961. Differences in plant numbers were significant at the 1% level and in the number of roots at the 5% level. The significant two-way table for the number of roots is shown below, while the corresponding table for the number of plants is given in Appendix B, Table 282.

Table 52. The mean number of roots at harvest in 1961 - method of singling x stage of singling.

	roots per acre		
	1st. Singling	2nd. Singling	
Uncouped	24,013	24,442	
Couped	22,485	24,040	S.E. = ± 335
Singled by hoe	20,529	22,793	

Where plants were left upright at singling, plant numbers were little affected by the stage at which they were singled, but when couped by hand or singled by hoe, fewer plants survived the earlier singling than the later one.

Growth Habit: The effect of the method of singling on growth habit is shown in Table 53.

Table 53. The effect of the method of singling on growth habit in 1960 and 1961.

Year	Percentage Prostrate			Percentage Erect		
	Uncouped	Couped	Singled by hoe	Uncouped	Couped	Singled by hoe
1960	24	50	-	13	9	-
1961	27	56	65	71	29	22

The effect of the method of singling on the percentage of roots prostrate and erect was significant at the 1% level. In 1961 singling by hoe tended to produce even more roots growing in the prostrate position and fewer growing erect than where the plants were deliberately couped by hand at singling, although the difference was non-significant. On average there were slightly more roots in the prostrate position in 1961 than in 1960, but there were also considerably more roots erect in the second year.

Growth habit in 1960 was not significantly affected by the stage at which the plants were singled, but in 1961, couping and singling/

singling by hoe gave considerably more plants in the prostrate position when singled at the later stage than at the earlier stage, while the stage of singling had little effect on the growth habit of the plants untouched at singling. This effect is shown in Table 54. The effect of the stage of singling on growth habit was significant at the 1% level and the method of singling x stage of singling interaction was significant at the 5% level.

Table 54. The percentage of plants prostrate in 1961 - method of singling x stage of singling.

	Percentage Prostrate		
	1st. Singling	2nd. Singling	
Uncouped	28	25	
Couped	42	70	S.E. = ±5
Singled by hoe	58	73	

The method of singling x stage of singling interaction was also significant, though only just so, for the percentage of plants erect in 1960. Here there tended to be more plants left erect after the later singling where the plants were not couped, but the stage of singling had little effect on the percentage of plants erect when they were couped at singling.

<u>Disease:</u> As in the results from Section E, there was no evidence that the treatment of the plants at singling affected their susceptibility to /

to disease. In 1960 the plants left erect at singling yielded 650 diseased roots per acre weighing 32.4 cwt., and the couped plants 633 diseased roots per acre weighing 31.7 cwt. Disease was negligible in 1961.

(ii) <u>The effect of the method of sowing</u>.

<u>Emergence</u>: In 1960 the turnip barrow produced a braird of 9.7 plants per foot, precision sowing without additional rolling gave 4.0 plants per foot, while precision sowing and rolling with the notched drill roller gave 6.0 plants per foot. The difference between the two precision seeding treatments was significant at the 1% level. In 1961 the turnip barrow gave a braird of 12.7 plant per foot, precision sowing without additional rolling gave 6.7 plants per foot, and with the notched drill roller, 6.3 plants per foot. The difference between the precision seeding treatments was non-significant.

<u>Crop yield and plant numbers</u>: The yields and plant numbers for the three sowing methods are given in Tables 55 and 56 respectively. There were no significant differences between any of the sowing methods in the yield of roots or the yield of dry matter in 1960, but as might be anticipated from the inferior braird, the precision sown plots (those without additional rolling) produced fewer plants after singling, and fewer sound roots at harvest (P = .05). The effect of the method of sowing on the yield of roots was still non-significant after covariance analysis (Table 49).

In 1961 there were no significant differences in plant numbers at singling or in the number of roots at harvest, but where the notched drill /

Table 55. The effect of the method of sowing on the yield of sound roots, the yield of dry matter in the sound roots, the dry matter percentage, and the yield of tops, in 1960 and 1961.

Method of Sowing	Yield of roots tons/acre			Dry Matter percentage %			Yield of dry matter cwt./acre			Yield of tops tons/acre		
	1960	1961	Mean	1960	1961	Mean	1960	1961	Mean	1960	1961	Mean
Turnip barrow	39.1	38.1	38.6	9.59	9.57	9.58	74.4	72.8	73.6	3.58	3.71	3.65
Precision seeder with plain diabolo rollers	38.1	36.6	37.4	9.76	9.52	9.64	73.4	69.7	71.6	3.61	3.92	3.77
Precision seeder with notched drill rollers	38.1	33.6	35.9	9.63	9.78	9.71	75.0	65.6	70.3	3.65	3.81	3.73
S.E.	± 0.59	± 0.97		± .07	± .06		± 1.40	± 2.02		±0.13	±0.19	

Table 56. The effect of the method of sowing on the post-singling plant count and the number of sound roots harvested, in 1960 and 1961.

Method of Sowing	Post-singling plant count plants/acre		Number of sound roots harvested roots/acre	
	1960	1961	1960	1961
Turnip barrow	19,345	23,859	17,405	22,774
Precision seeder with plain diabolo rollers	18,144	24,287	15,893	23,223
Precision seeder with notched drill rollers	18,942	24,214	17,052	23,256
S.E.	± 309	± 225	± 336	± 338

drill roller was used, the precision seeder gave 4.5 tons of roots per acre less than the turnip barrow. This yield difference was significant at the 5% level. It can be seen in Table 55 that the dry matter percentage of the roots for this treatment was more than 0.2% higher than for the other sowing methods, and although this effect failed to reach significance (with 6 d.f., V.R. = 4.92; F.05 = 5.14) it did result in a non-significant effect in terms of dry matter yield. The roots precision sown without additional rolling were 1.5 tons per acre lower than those sown with the turnip barrow, but this difference was non-significant.

The method of sowing was not significantly affected by any of the singling treatments in either of the experiments, and there was no significant difference in the yield of tops from the different sowing methods.

<u>Growth Habit</u>: The method of sowing had no significant effect on growth habit in 1960, but had a considerable effect in 1961, as can be seen from Table 57.

Table 57. The effect of the method of sowing on growth habit in 1961.

Method of sowing	Percentage Prostrate	Percentage Erect
Turnip barrow	63	29
Precision seeder	49	38
Precision seeder with notched roller	35	55
S.E.	± 3	± 5

The /

The effect of the method of sowing on the percentage of roots in the prostrate position was significant at the 1% level, and on the percentage of roots erect, at the 5% level. The precision sown swedes were clearly much more erect in growth habit than those sown with the turnip barrow, the additional rolling tending to further increase the erectness of the crop.

In neither of the years was there any evidence of an interaction between the method of sowing and the method of singling on the growth habit.

<u>Discussion:</u>

<u>The effect of exposing the hypocotyl when singling:</u> The results of the growth habit estimations leave no doubt about the effect of exposing the hypocotyl at singling on the growth habit of the mature plant. On average, 22% of the plants left erect at singling, and 50% of those couped were growing in a prostrate position at maturity. It is difficult to account for the low average number of plants growing prostrate in Section E, 1961, compared to the other experiments; and again, since on average 22% of those plants left erect at singling were prostrate at maturity, it is obvious that factors other than the treatment of the plant at singling are responsible for the irregularity of growth habit. Coarseness of tilth, lack of moisture, and wind force are possible ecological causes, but heredity may also play some part.

The results also show that exposing the hypocotyl when singling is likely to reduce plant numbers: a significant loss in plant numbers due /

due to couping occurred in 3 experiments out of 4. The majority of the plant losses occurred during the first two weeks after singling. In 2 of the 3 experiments where there was a loss of plants due to couping, and where the post-singling count was not taken until about 18 days after singling commenced, there was virtually no difference in mortality rate between the couped and uncouped plants. When, however, the plant count was made only 10 days after singling in 1961 (Section E) the percentage mortality of the couped plants was $2\frac{1}{2}$ times that of the uncouped plants, resulting in a significantly lower number of roots at harvest. None of the plant losses appeared to be due to Strangles, even at the earlier stage of singling (Section F).

It seems fairly clear from the experiments that yield losses may occur as a result of exposing the hypocotyl at singling, but that any loss is likely to be small unless the plant population is already so low that further reduction results in yield losses. The average loss in yield due to exposing the hypocotyl was 1.3 tons per acre. On the other hand, the results of the 1961 experiment (Section F) which was a precise experiment with a coefficient of variation of 5.6% suggests that in some circumstances, loss in yield may not occur at all as a result of exposing the hypocotyl.

Apart from the influence which loss of plants may have on the yield of roots, there would seem to be two possible ways in which the growth of plants and their subsequent yield might be affected by /

by couping at singling, namely, (a) the plants may receive a greater check to early growth compared to those plants left erect, and/or (b) any effect of couping on growth habit may be detramental to the efficiency of photosynthesis since the 'lower' leaves of a prostrate plant suffer considerable shading. Caldwell (1929) has shown that where plants are prostrate in growth habit, the root develops abnormally since the deposition of foodstuff is concentrated in the upper side of the root due to greater metabolism taking place in the upper and more exposed leaves. Table 58 shows, however, that there appears to be no direct relationship between the difference in the percentage of roots prostrate from the couped and uncouped plots, and the loss in yield due to couping.

Table 58. The difference in the percentage of plants prostrate between the couped and uncouped plots, and the percentage loss in yield due to couping.

	Percentage Prostrate Couped minus Uncouped	Yield (Percentage loss) Uncouped minus Couped
Section E, 1960	26.8	6.2
Section E, 1961	9.4	3.8
Section F, 1960	26.6	3.0
Section F, 1961	29.7	-0.5

Although /

Although other ecological factors may intervene here, the figures show that the abnormal root shape associated with prostrate growth does not appear to be accompanied by a corresponding loss in yield, and, therefore, a differential check at singling seems more likely be the chief factor responsible for any loss of yield due to couping. In 1961 (Section F), despite a difference of 30% in the number of roots growing in the prostrate position, no loss of yield was incurred by couping, and it may be that growth was so restricted in the early stages in this experiment by the dry cold weather from sowing until long after singling that it made little difference whether the plants were couped or not, and here the stage at which the plants were singled was more important than the way in which they were singled.

Since the post-singling plant count was not made until 18 days after singling in the 1961 experiment, it is impossible to say how much of the loss in plant numbers, when singling was done with the hoe, was due to plants dying off after singling or to a large number of plants knocked out when singling along the marked string. As already suggested in the results, it seems unlikely in view of the results of the population studies (Section G) that this loss of plants affected root yield, and therefore it is difficult to account for the lower yield of those plants singled by hoe. Certainly, no conclusion can be drawn from the result of one experiment.

Stage of singling: The two stages of singling were included in the experiments /

experiments to see if any effect of couping was influenced by the stage of growth at which couping occurred. The main effects of the stage of singling, however, is of interest.

The loss in yield of 1.4 tons of roots per acre with the later singling in 1961 agrees to some extent with previous work (Holmes and Lang, unpublished) though a loss of 1.4 tons is larger than that obtained previously with similar stages of singling. In 6 experiments, singling at the 5- to 6- leaf stage reduced the yield of roots by an average of 0.5 tons per acre, while singling at the 8- leaf stage reduced the yield by 0.9 tons per acre. There was no evidence that loss of yield with late singling was more serious where swedes were sown with the turnip barrow than where precision sown. In Bulletin 3 of the Ministry of Agriculture, Fisheries and Food (1953) in 5 experiments with sugar beet, only 1 experiment showed a slight loss of yield by singling at the 6-true leaf stage compared to the 2- and 4-true leaf stage. In all the experiments a further delay in singling reduced the yield of roots, and the loss of yield was greater where natural as opposed to rubbed seed was used. With natural seed, the average yield of beet was 1.6 tons per acre less than where the crop was singled at the optimum stage; with rubbed seed, there was less overcrowding and the corresponding reduction in yield was 0.9 tons per acre. It was considered essential that plant competition be relieved in the early stages, that is, by the 6-true leaf stage.

It would appear that swedes are less sensitive than sugar beet to the effect of inter-plant competition, and, in the absence of any interaction /

interaction between sowing method and stage of singling in the previous experiments with swedes, it would appear that competition was not responsible for the small yield losses which occurred with late singling, but that this was due to a more severe growth check when the plants were large. Certainly, when further developed, the root system would be more susceptible to damage by hoeing. The results of the present experiments also suggest that any growth check is not only dependent on the size of the plant, but on soil and weather conditions around singling time. Thus early singling in 1960, when the tilth was very coarse and anything but a good medium of support for a very small seedling, gave 1.5 tons of roots per acre less than the later singling - though loss of plants may have been partly responsible for this. In 1961, when a loss of 1.4 tons of roots per acre was incurred by singling at the 5- to 6- leaf stage, conditions were very cold and dry from singling onwards and were even less conducive to plant recovery and growth at the later stage of singling than at the first singling.

The results also showed that early singling is likely to produce a lower plant stand than singling at the 5- to 6- leaf stage. This agrees with the results of Whybrew (1958) who found that the highest sugar beet populations were obtained by singling at the 4-leaf stage. Singling at the 2-or6- leaf stage reduced plant stand.

Although the stage of singling had no significant effect on growth habit in 1960, the results of 1961 showed that where plants were /

were couped by hand or singled with the hoe, the effect was less harmful to an erect growth habit with early singling than with later singling. At the early stage of singling, the plants were on average at the 2- to 3- rough leaf stage, but owing to the irregular braird, many of the singled plants were at the cotyledon or 1- leaf stage. Plants at this stage of growth could not be couped over so effectively as larger plants without the risk of knocking the plants out. This may have been partly the reason for the less harmful effects of couping on growth habit at the earlier stage of singling.

Method of sowing: Before considering the results of the present experiments, it is pertinent to look at the results of previous experiments comparing the turnip barrow and the precision seeder (Holmes and Lang, unpublished). Six experiments were carried out between 1957 and 1960 to study the effect of late singling on barrow-sown and precision-sown swedes. One experiment was laid down in 1957, two in 1958 and 1959, and one in 1960. In 1957, in both sites in 1959 and in 1960, the turnip barrow gave a significantly lower yield of dry matter than the precision seeder sowing at 2- inch spacing, but in both sites in 1958, the turnip barrow gave slightly higher yields (non-significant) than the precision seeder. In the present experiments there were no significant differences in the yield of roots sown with the turnip barrow and those precision sown and rolled with the plain diabolo rollers, though on average the turnip barrow yielded 1.5 tons of roots per acre more than the precision /

precision seeder sowing at 1½ inches. Averaging the results of all the experiments between 1957 and 1961, precision sowing at 1½ to 2 inches gave 66.0 cwt. per acre of dry matter, while the turnip barrow gave 65.3 cwt. per acre. This agrees with Robertson (1961) who found no significant differences in the yield of roots from the turnip barrow and the precision seeder sowing at 1- and 2- inch spacing.

As already stated, there was no evidence of an interaction between the method of sowing and the way in which the plants were singled, either for root yield or growth habit. In precision sowing, the seed goes into the ground in front of a small roller; with the turnip barrow, the seed drops from the coulter into a fairly loose tilth and is covered with soil by a small drag chain. The rolling after sowing provided by the precision seeder, and the additional rolling with the notched roller, it was thought, might give some support to the seedlings, thereby producing more erect growth, and also make it more difficult to coup the plants when singling with the hoe. It was also thought that plants growing closely together might tend to be more easily couped when singled by hoe, than plants precision sown. There was no evidence, however, that singling with the hoe gave fewer plants growing erect when sown with the turnip barrow than when precision sown. Nevertheless, the 1961 experiment showed that precision seeding, particularly where additional rolling was carried out, is likely to produce plants more erect in growth habit /

habit than sowing with the turnip barrow, and it is conceivable that this may have contributed to the lower yields with the barrow-sown swedes in the 'method of sowing x stage of singling' experiments in 1957, 1959 and 1960. It seems more likely that the relative merit of the two sowing methods in terms of yield is dependent on the weather at sowing time and on soil conditions: in dry conditions, the compaction of the seed-bed provided by the precision seeder may be beneficial to emergence and early growth; in wet conditions the reverse may be the case. The effect of rolling is discussed more fully below. Since any difference in yield between swedes sown with the turnip barrow and swedes precision sown at 1½ or 2 inches is likely to be small, yield is not a factor that need be considered in any choice of sowing methods.

The depression in yield due to the additional rolling with precision sowing in 1961 requires some explanation. Since the three sowing methods did not differ significantly in plant numbers, and the precision-sown treatments had almost the same plant population, the high dry matter percentage of the roots from those plots precision sown and rolled with the notched roller, confirms that the roots had been restricted in size (the dry matter percentage of a root being inversely related to its size.). The effect of compacting the seed-bed, therefore, had been to restrict plant growth - probably in the early stages.

Russell and Keen (1939) found that heavy rolling of the seed-

bed /

bed did not lead to any improvement in the yield of sugar beet, and although it increased plant numbers somewhat when plant numbers were high, it led to no improvement when they were low. This work was carried out for two years, and although none of the effects were significant, the yield responses to rolling were negative in both cases, even where plant numbers had been increased by rolling. Nitzsh (1936) found that rolling the seed bed usually depressed the yield either of sugar beet or mangolds, and the depression was greater the heavier the roller. Since compaction of the seed bed is really a mechanism by which the air and moisture supply in the seed bed is controlled, the work of Heydecker (1960) is of interest here. Heydecker, in experiments with various vegetable seeds, demonstrated the complementary importance of maintaining both moisture and air supply for germination and early growth, and showed that species were very specific in their tolerance to environment. He showed with peas, that where germination had been delayed through lack of moisture, germination and growth proceeded normally once moisture was made available, but where seeds were exposed to drought after their radicles began to emerge, growth was permanently checked. These experiments show that soil conditions for maximum germination and subsequent growth are fairly critical, particularly in regard to the air/moisture balance.

In the experiments reported here, when the seed bed was very coarse and dry in 1960, compaction was limited by these conditions but /

but was sufficient to conserve some moisture, which increased germination and resulted in a better plant stand. In 1961, when there was a fine moist seed bed, the additional rolling restricted growth. It may be that germination commenced in the moist conditions at sowing, but in the dry, cold weather which followed, growth was restricted by the compacted seed bed. Although moist or wet conditions appear to be the chief pre-disposing factor to yield losses through rolling, the exact combination of soil and weather conditions most likely to cause yield losses in this way is not known, and it may be that where moist conditions at sowing are not followed by drought, there are no harmful effects.

Robertson (1959) showed that where swedes were precision sown at 2-inch spacing, the saving in hand labour following mechanical thinning was only 9% compared to 45% with the turnip barrow, and suggested that this relatively small saving in labour may not be worth while. Although the use of the notched roller may be an aid to efficient mechanical thinning, the economics of mechanical thinning after precision seeding are therefore much in doubt. In addition, the procedure of rolling is not without risk to crop yield and can only be recommended in conditions where the soil is dry, when some advantage in plant stand might be expected.

Conclusions:

Growth habit:

(1) Exposing the hypocotyl when singling, greatly reduces the /

the number of plants growing erect at harvest, and there was some evidence to suggest that the effect of couping on the erectness of the crop is greatest when the plants are large.

(2) There was some evidence to show that swedes, precision sown, may grow more erect than swedes sown with the turnip barrow, and that additional rolling further increases the erectness of the crop.

(3) There was no evidence to show that the effect of couping or singling with the hoe was influenced by the method of sowing.

Yield and plant numbers:

(4) Couping the plants at singling is likely to reduce plant numbers and produce a small loss of yield.

(5) The extent to which yield is affected by couping appears to be seasonal, and the loss of yield due to couping appears to be due to a growth check at singling, rather than to prostrate growth habit and the associated abnormal root shape.

(6) Loss of plant numbers due to couping tends to be greatest when the plants are small at singling.

(7) There was no evidence to show that the effect of couping or singling with the hoe, on crop yield, was influenced by the method of sowing.

Considering the results of the present experiments along with the results of the previous experiments to study the effect of the the method of sowing on the stage of singling (Holmes and Lang, unpublished /

unpublished), the following conclusions may be drawn:

(8) Any difference in yield between swedes precision sown at $1\frac{1}{2}$- or 2 inch-spacing and those sown with the turnip barrow, is probably due to the greater compaction given to the seed-bed by the precision seeder. The advantage of either method is, therefore, dependent on soil conditions at sowing. Over a number of years, there is likely to be little difference in yield between the two methods.

(9) Additional rolling with a notched drill roller assists plant emergence in dry conditions, but in moist conditions, particularly if followed by drought, yield losses are likely.

(10) There is no greater loss in yield from late singling where swedes are barrow sown than where precision sown.

(11) Differences in yield due to stage of singling appear to be dependent as much on soil conditions at singling as on the stage of plant growth.

G. The Effect of Plant Population and Plant Distribution on the Yield and Quality of Roots.

Introduction:

When unwanted seedlings are removed by mechanical methods such as gapping, and down-the-row thinning, which may or may not be followed by hand trimming, a more irregular plant stand is obtained than from traditional hand singling. Precision seeding at wide intervals can also result in very irregular inter-plant spacing.

The object of this experiment was to determine the effect of irregular plant distribution on the yield of roots, and the influence of the plant population level on this effect.

Method:

The layout consisted of a 3^2 factorial in randomized blocks. Four replications were laid down in 1960, and 6 in 1961. Treatments were:-

Plant spacing:

1 - 8 inch mean spacing

2 - 12 inch mean spacing

3 - 16 inch mean spacing

Distribution:

A - Regular

B - ½ irregular, equivalent to singling with a hoe.

C - Very irregular, equivalent to mechanical thinning followed by hand trimming.

Treatment /

Treatment A is never achieved in practice. Treatment B, in which the distribution was ½ irregular and which is comparable to normal singling with a hoe, was obtained from a histogram produced by Thomson (1956). Treatment C was obtained from a histogram of a field trial carried out by Robertson (1960) in which the final plant stand was got by going twice through a crop sown with Hudson seed-boxes at 3 1/2 lb. per acre, with a mechanical thinner, followed by hand singling. A histogram was then prepared for each of the two irregular treatments (B and C) at each mean spacing. Figures 12 and 13 show respectively the intended distribution of gap lengths for treatments B and C, having 16-inch mean spacing. For 8-inch and 12-inch mean spacing, horizontal scales are in proportion.

To ensure a random distribution of gaps within each treatment, cards were marked with gap lengths, the number of cards for each gap corresponding to the frequency with which the gap occurred as shown in the histogram. The cards were then mixed and chosen at random. The distribution of gaps thus obtained was marked on twine with black paint, and when stretched along a plant row, formed a pre-arranged singling pattern.

The trial area was precision sown at 1 1/2-inch spacing and plots were marked off at brairding. These were 20 yards long x 4 drills each 27 inches wide. The singling patterns were 26 yards long and were moved into different positions in each of the plot rows, so that the plants in the 4 rows were not directly opposite one another /

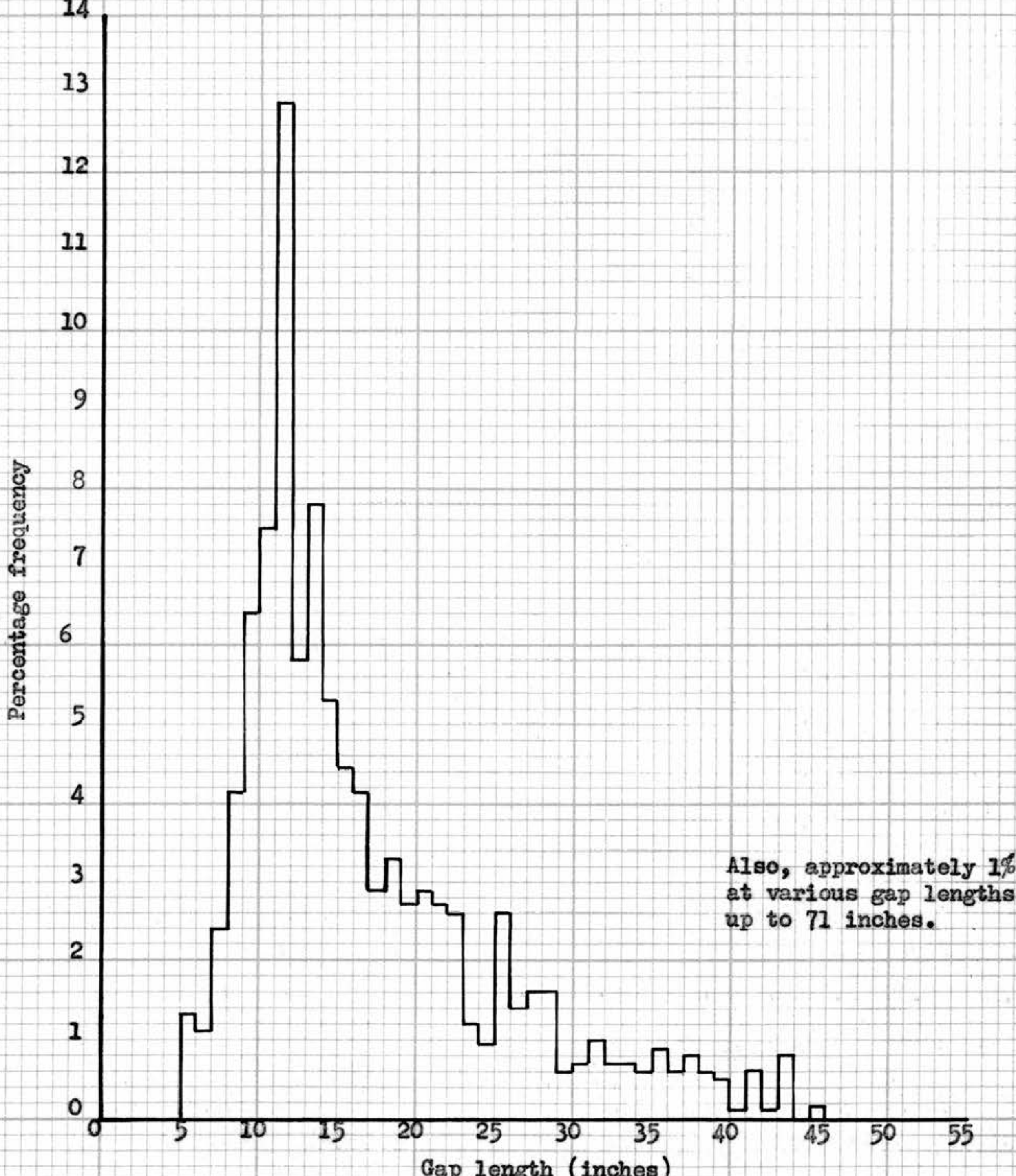


Figure 13. Intended distribution of gap lengths, 16-inch mean spacing, for treatment C (very irregular) - Robertson (1960).

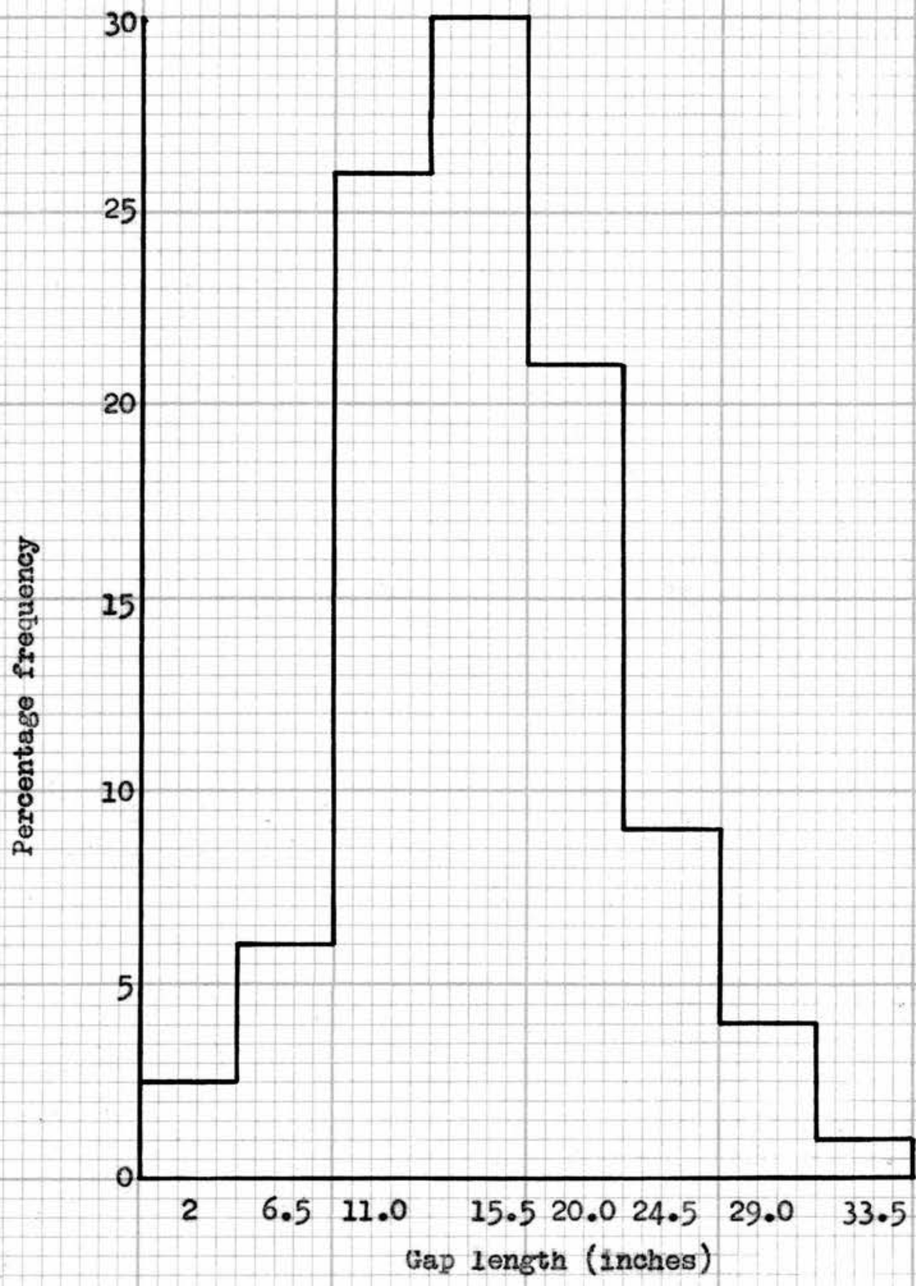


Figure 12. Intended distribution of gap lengths, 16-inch mean spacing, for treatment B ($\frac{1}{8}$ irregular) - Thomson (1956).

another. Only the middle 2 rows of each plot were harvested, the plot area being 1/160 acre.

In 1960, the seed (variety Broadland) was sown in a fine tilth on the 5th May in rather dry conditions. The trial brairded on the 15th May and the briard was fairly even, except in Block I where the conditions seemed to be driest. The drills were scarified on the 4th June, and Block II, III, and IV were singled on the 7th and 8th June. Block I was singled on the 11th June. Inter-row cultivations were carried out as for the commercial crop.

In 1961, the variety, Bronze Top was sown on the 12th May. The crop brairded rather slowly in the dry conditions, on the 24th May. The briard, however, was a good one. The drills were scarified on the 23rd June and singling took place on the 26th and 27th June. As in 1960, inter-row cultivations were carried out as for the commercial crop.

Details of soil analysis, preceeding crop, and fertiliser application are given in Appendix A.

In both trials a post-singling plant count was taken shortly after singling.

After the initial dry spell in 1960, the crop grew quickly in the moist conditions of that year, and gave an average yield of 39.2 tons per acre when harvested during the first week in January. In 1961, the experiment was harvested during the last week of November and yielded on average 32.7 tons per acre.

Results /

Results:

The effect of plant distribution is considered first, while the main effects of populations are discussed along with the results of the population studies in Sections C and E.

Plant numbers: The number of plants remaining after singling, and the number of sound roots harvested from the 3 plant distributions are given in Table 59. In 1960 there were no significant differences in the number of plants remaining after singling or the number of roots harvested, but in 1961 although the treatment main effects were non-significant, there was a significant spacing x distribution interaction for the number of plants remaining after singling (P = .01), (Table 60).

Table 60. The number of plants remaining after singling for each distribution at 8-, 12- and 16-inch mean spacing in 1961.

Distribution.	Plants per acre Mean spacing (inches).			
	8	12	16	
Regular	27,148	18,224	14,392	
½ irregular	27,175	17,527	14,686	S.E. = 214
Very irregular	26,291	18,170	14,526	

At 12- and 16-inch mean spacing, the plant population at regular spacing was little different from the two irregular spacing treatments /

Table 59. The number of plants remaining after singling and the number of sound roots harvested from regular, $\frac{1}{8}$ irregular and very irregular distribution, in 1960 and 1961.

Distribution	Post-singling plant count plants per acre			Number of sound roots harvested roots per acre		
	1960	1961	Mean	1960	1961	Mean
Regular	21,038	19,936	20,487	20,234	18,774	19,504
$\frac{1}{8}$ irregular	21,480	19,811	20,645	19,805	18,685	19,245
Very irregular	20,984	19,677	20,330	19,899	18,515	19,207
S.E.	± 322	± 124		± 386	± 216	

Table 61. The mean effect of irregular spacing on the yield of sound roots, the dry matter percentage and the yield of dry matter in the sound roots, in 1960 and 1961.

Distribution	Yield of roots tons per acre			Dry matter per cent.			Yield of dry matter cwt. per acre		
	1960	1961	Mean	1960	1961	Mean	1960	1961	Mean
Regular	40.3	32.7	36.5	10.37	9.51	9.94	83.6	62.1	73.0
$\frac{1}{8}$ irregular	38.5	33.0	35.7	10.30	9.41	9.85	79.0	62.0	70.5
Very irregular	38.8	32.5	35.7	10.51	9.44	9.97	81.6	61.4	71.5
S.E.	± 0.54	± 0.38		± .08	± .11		±1.3	±1.1	

treatments, but at 8-inch mean spacing, the very irregular distribution was 900 plants per acre lower than the regular and ½ irregular distributions. In practice, irregularities in the braird made it difficult to leave plants at the desired places along the marked strings, and the greatest difficulty was experienced with the closest spacing. There was a similar effect on the number of roots harvested, but from the results of the plant population studies, it is very unlikely that small differences at this population level would have any effect on yield.

Crop yield: The effect of irregular plant distribution on the yield of sound roots and the yield of dry matter in 1960 and 1961 is shown in Table 61. The effect of irregular distribution on the yield of roots and on the dry matter percentage of the roots was non-significant in both years, but in 1960 the ½ irregular distribution yielded 4.6 cwt. per acre of dry matter less than the regular distribution. The very irregular distribution yielded 2.0 cwt. per acre less than the regular distribution. This effect of irregular distribution on the yield of dry matter was significant at the 5% level. The 3 distributions did not differ significantly in dry matter yield in 1961. Little significance can be attached to the lower yield of dry matter from the 'hand-singling' treatment compared to the 'mechanical thinning' in 1961. This was probably a result of the very poor braird in one of the ½ irregular plots and to a patch of 'finger-and-toe' in another. On average, the ½ irregular distribution gave ½ ton of diseased roots more /

more than the regular or very irregular distribution.

There tended to be a slightly greater loss of yield due to very irregular distribution at the 16-inch mean spacing than at closer spacing (Table 62), but the spacing x distribution interaction did not approach significance for the yield of roots or the yield of dry matter in either of the experiments.

Table 62. The effect of plant distribution on the yield of sound roots at 8-, 12- and 16- inch mean spacing, averaged for 1960 and 1961.

Distribution	tons per acre			
	Mean spacing (inches)			
	8	12	16	
Regular	36.7	36.7	36.1	
½ irregular	35.7	36.6	34.9	S.E. = ± 0.72
very irregular	36.0	36.1	34.8	
Loss due to very irregular distribution	0.7	0.6	1.3	

The mean effect of very irregular plant distribution at 16-inch mean spacing, although about twice that where plant distribution was regular, was still small, namely, 1.3 tons per acre.

Results of plant population studies.

The results of the plant population studies in Sections C, E and /

and G are collated and discussed here. Table 63 shows the plant spacings and population levels studied in each section.

Table 64 gives the theoretical and actual population for each plant spacing averaged for all experiments in Section C, E and G. The percentage 'loss' of plant numbers was much greater at close spacing than at wide spacing, due not only to the greater difficulty of maintaining plant numbers at singling where the braird was poor, but also to a higher mortality rate. At the widest spacings there was a tendency for plant numbers to be slightly above the intended population. Other workers have also found difficulty in producing theoretical populations in the field. Whitehead (1935) found that plant losses occurred at all populations levels with the greatest losses occurring at the closest spacing. Anon, (1906) found that losses occurred at the closest spacings but at the widest spacing the actual population was above the theoretical, and where intended plant spacings were 6, 11, 16 and 21 inches, the actual spacing was 8½, 11, 16 and 18 inches.

<u>Yield of roots and dry matter:</u> Table 65 gives the mean yield of sound roots and the mean yield of dry matter for each plant spacing in each year of trial for Section C, E and G.

The only significant effect of plant spacing on the yield of roots was in Section C in 1960 when 16-inch spacing gave the lowest yield of roots - 1.9 tons per acre lower than for 5-inch spacing - but a study of the mean root yields in the field trials at least

(Sections /

Table 63. The plant spacings, row widths and population extremes in Sections C, E and G.

Section	C	E	G
Number of years of trial	2	3	2
Spacing	5, 8, 11 and 14 inches	5, 8, 11 and 14 inches	8, 12 and 16 inches
Row width	20 inches,	27 inches	27 inches
Population extremes*	22,300 - 53,000	15,800 - 38,800	14,500 - 25,300

* the total root count at harvest.

Table 64. The theoretical plant population, the mean number of roots at harvest, and the percentage deficit of plants at each plant spacing in Sections C, E and G.

Section	Plant spacing	Theoretical population	Mean number of roots at harvest	Deficit
	inches	plants per acre	roots per acre	per cent.
C	5	62,720	52,321	16.6
	8	39,168	36,621	6.5
	11	28,416	28,180	0.8
	14	22,528	22,969	+ 1.9
E	5	46,368	34,581	25.4
	8	28,980	25,053	13.6
	11	21,091	19,776	6.2
	14	16,583	16,236	+ 2.1
G	8	28,980	25,900	10.4
	12	19,320	18,297	5.3
	16	14,490	15,288	6.7

Table 65. The mean yield of sound roots, the yield of dry matter in the sound roots, and the number of sound roots harvested at each plant spacing, in Sections C, E and G.

Section	Spacing	Mean number of roots, roots per acre	Yield of roots. tons per acre				Yield of dry matter cwt. per acre			
			1959	1960	1961	Mean	1959	1960	1961	Mean
C	5	51,703	25.0	-	37.1	31.1	59.6	-	80.6	70.1
	8	36,185	25.7	-	36.9	31.3	62.8	-	80.3	71.5
	11	27,733	25.8	-	38.0	31.9	61.2	-	82.7	71.9
	14	22,446	25.8	-	35.9	30.9	58.6	-	75.0	66.8
	S.E.		± 0.65	-	± 1.46	-	± 0.6	-	± 1.9	-
E	5	34,438	25.4	43.7	39.4	36.2	57.4	85.4	77.7	73.5
	8	24,834	26.0	44.0	38.5	36.2	57.2	84.8	76.2	72.7
	11	19,439	27.0	43.2	37.3	35.8	58.1	81.8	72.9	70.9
	14	15,709	26.1	41.8	38.0	35.3	55.7	77.8	72.3	68.6
	S.E.		± 0.42	± 0.54	± 0.65	-	± 0.7	± 1.2	± 1.7	-
G	8	25,489	-	39.2	33.1	36.1	-	82.8	63.0	72.9
	12	17,844	-	40.0	32.9	36.4	-	82.8	62.2	72.5
	16	14,622	-	38.4	32.1	35.3	-	78.6	60.6	69.6
	S.E.		-	± 0.54	± 0.38	-	-	± 1.3	± 1.1	-

(Sections E and G), suggests that some small loss of yield was incurred at the widest spacing. Figure 14, which shows the mean yield of sound roots and the mean yield of all roots at each population level, reveals, however, that the effect of wide spacing on the yield of roots was not a direct population effect but a result of a larger weight of diseased roots at the widest spacing compared to closer spacing. It can be seen in Figure 14 that in none of the population studies was the total yield of roots less at the widest spacing than at the closest spacing - even in Section G, where any effect that irregularity had, was included in the main effect of plant spacing.

The effect of plant population on the yield of dry matter is shown graphically in Figure 15, the yield of dry matter being calculated from the product of the dry matter percentage and the yield of sound roots. In all three series of experiments, the widest spacing, on average, resulted in loss of dry matter, and in Sections E and G there was a gradual loss of dry matter production as the population level decreased. This was a result of the higher yield of diseased roots from the widely spaced plants and also to the lower dry matter percentage of the large roots. The effect of plant spacing on the yield of dry matter was significant at the 5% level in Section C (1961), significant at the 1% level in Section E (1960) and just failed to reach significance in Section G in 1960.

Disease: In the field trials, where disease was severe enough to be considered /

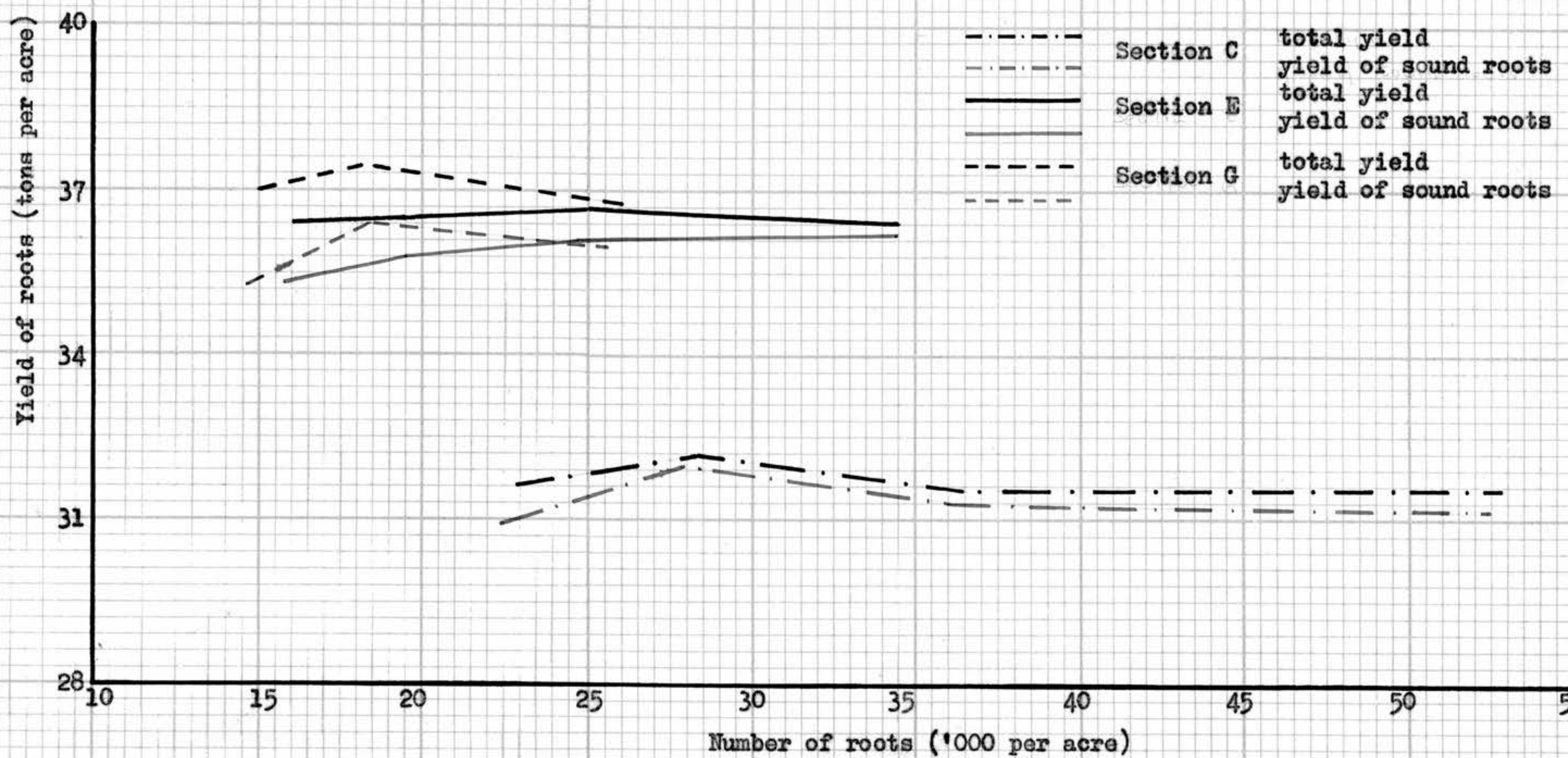


Figure 14. The mean effect of plant population on the total yield of roots and on the yield of sound roots, Section C, Section E and Section G.

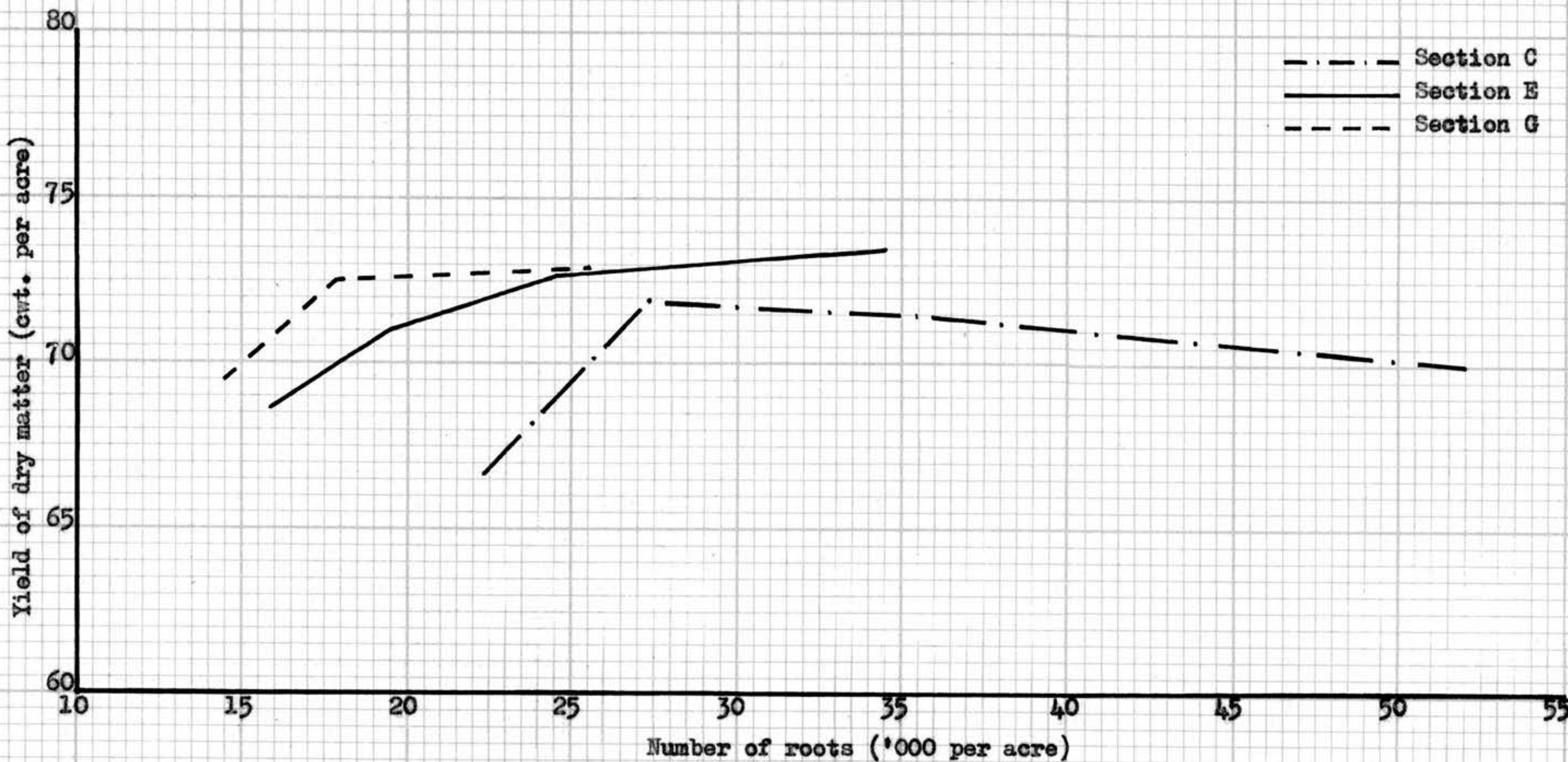


Figure 15. The mean effect of plant population on the yield of dry matter in the sound roots, Section C, Section E and Section G.

considered, there was on average approximately $\frac{1}{2}$ ton per acre of diseased roots at close spacing, and $1\frac{3}{4}$ tons per acre at the widest spacing. The higher yield of diseased roots at wide spacing was due not only to the larger size of the roots but to a higher incidence of disease. At the widest spacing, there were on average approximately twice as many diseased roots as at the closest spacing. This was very largely a result of physiological splitting. The term 'diseased' roots includes a few severely split roots showing no definite signs of infection but which were breeding grounds for bacterial rot. Table 66 gives the number and yield of diseased roots at each plant spacing.

Table 66 /

Table 66. The number and yield of diseased roots at each plant spacing in Sections C, E and G.

Section	Plant spacing inches	Number of diseased roots roots per acre			Weight of diseased roots cwt. per acre		
		1959	1960	1961	1959	1960	1961
C	5	1363	-		14.7	-	
	8	873	-	disease	9.7	-	disease
	11	895	-	negligible	15.4	-	negligible
	14	1044	-		24.3	-	
	S.E.				±5.27		
E	5	94	335		3.4	11.7	
	8	308	322	disease	11.9	15.5	disease
	11	415	616	negligible	17.8	27.7	negligible
	14	710	871		21.1	47.1	
	S.E.				±4.03	±4.20	
G	8	-	402	420	-	13.6	12.9
	12	-	388	518	-	19.2	23.0
	16	-	563	769	-	26.8	39.3
	S.E.					±3.46	±4.18

<u>Section C</u>: There were no significant effects of spacing on the yield and number of diseased roots in 1959, but here the normal pattern of disease incidence was upset by patches of 'finger-and-toe'. In 1961 disease incidence was negligible.

<u>Section E</u>: Increasing the plant spacing significantly increased the yield and number of diseased roots in 1959 ($P = .05$) and 1960 ($P = .01$). Disease incidence in 1961 was negligible. In 1959 no dry rots (<u>Phoma lingam</u>) were observed, and almost all the diseased roots were affected by bacterial wet rot (<u>Bacillus caratovorous</u>). In 89% of the wet rots, infection had entered through a split in the root. In 1960 splitting was again the predisposing factor in 77% of the cases of bacterial rot, 34% of the split roots being a result of the 'many-necked' condition. The remaining 23% of rots were chiefly crown rots. Of the 18 diseased roots in 1961, half were a result of splitting.

<u>Section G</u>: The effect of spacing on the number of diseased roots was non-significant in 1961, but the effect on the yield of diseased roots was significant at the 5% level. In 1961 plant spacing significantly affected both the number and yield of diseased roots ($P = .01$), the widest spacing giving the largest number and highest yield of diseased roots. No observations were made as to the cause of disease in 1960, but in 1961, 88% of the rots were wet rots of which 82% were a result of splitting.

<u>Dry matter percentage</u>: Table 67 shows the effect of root size on dry matter /

Table 67. The effect of root weight on dry matter percentage, 1959 to 1961.

Section	Plant Spacing inches	1959 Mean root weight lb.	1959 Dry matter per cent.	1960 Mean root weight lb.	1960 Dry matter per cent.	1961 Mean root weight lb.	1961 Dry matter per cent.	Mean of 3 years Mean root weight lb.	Mean of 3 years Dry matter per cent.
1	5	1.1	12.48	-	-	1.5	10.91	1.3	11.69
	8	1.6	12.30	-	-	2.3	10.91	1.9	11.60
	11	2.1	11.91	-	-	3.1	10.78	2.6	11.34
	14	2.6	11.42	-	-	3.6	10.38	3.1	10.90
	S.E. of mean		± .13				± .21		
2	5	1.7	11.29	3.1	9.78	2.3	9.88	2.4	10.32
	8	2.4	11.02	4.1	9.62	3.3	9.89	3.3	10.18
	11	3.1	10.83	5.3	9.48	4.0	9.79	4.1	10.03
	14	3.9	10.69	6.1	9.33	5.0	9.53	5.0	9.85
	S.E. of mean		± .10		± .09		± .14		
3	8	-	-	3.4	10.58	2.9	9.51	3.1	10.04
	12	-	-	4.8	10.35	4.3	9.41	4.5	9.88
	16	-	-	5.5	10.23	5.2	9.44	5.3	9.83
	S.E. of mean				± .08		± .11		

matter percentage in each of the population studies, and the data are presented graphically in Figure 16. It is clear that on average, the smaller the root, the higher is its dry matter percentage, and this has been shown to be so by several workers (Berry - 1925, Hendrick and Greig - 1904, Collins - 1905, and Sansome - 1926 with swedes, and Wood and Berry - 1905, with mangolds), but although the size of the root is inversely related to its dry matter percentage, it does not appear to be proportional. There is some suggestion from Figure 16 that differences in root weight are accompanied by larger differences in dry matter percentage when the average root size is small, than when the average root size is large (though at the smallest root weight in Section C, the curve tends to level off). Where the average dry matter percentage was low as in the two lower lines on the graph, the dry matter percentage was less affected by changes in root size. A similar result was obtained with mangolds by Wood and Berry (1905) who found that a small change in weight made a large difference in dry matter percentage if the roots were small, but when the size of the root reached approximately 7 lb., alteration in root weight had a comparatively small effect on the dry matter percentage.

A likely explanation for the difference in dry matter percentage between roots of different sizes and for the variation in dry matter percentage/root size relationship, is the proportionally greater amount of skin and of the high dry matter area immediately below the skin, in small roots as opposed to large roots. Hendrick and Greig (1904) /

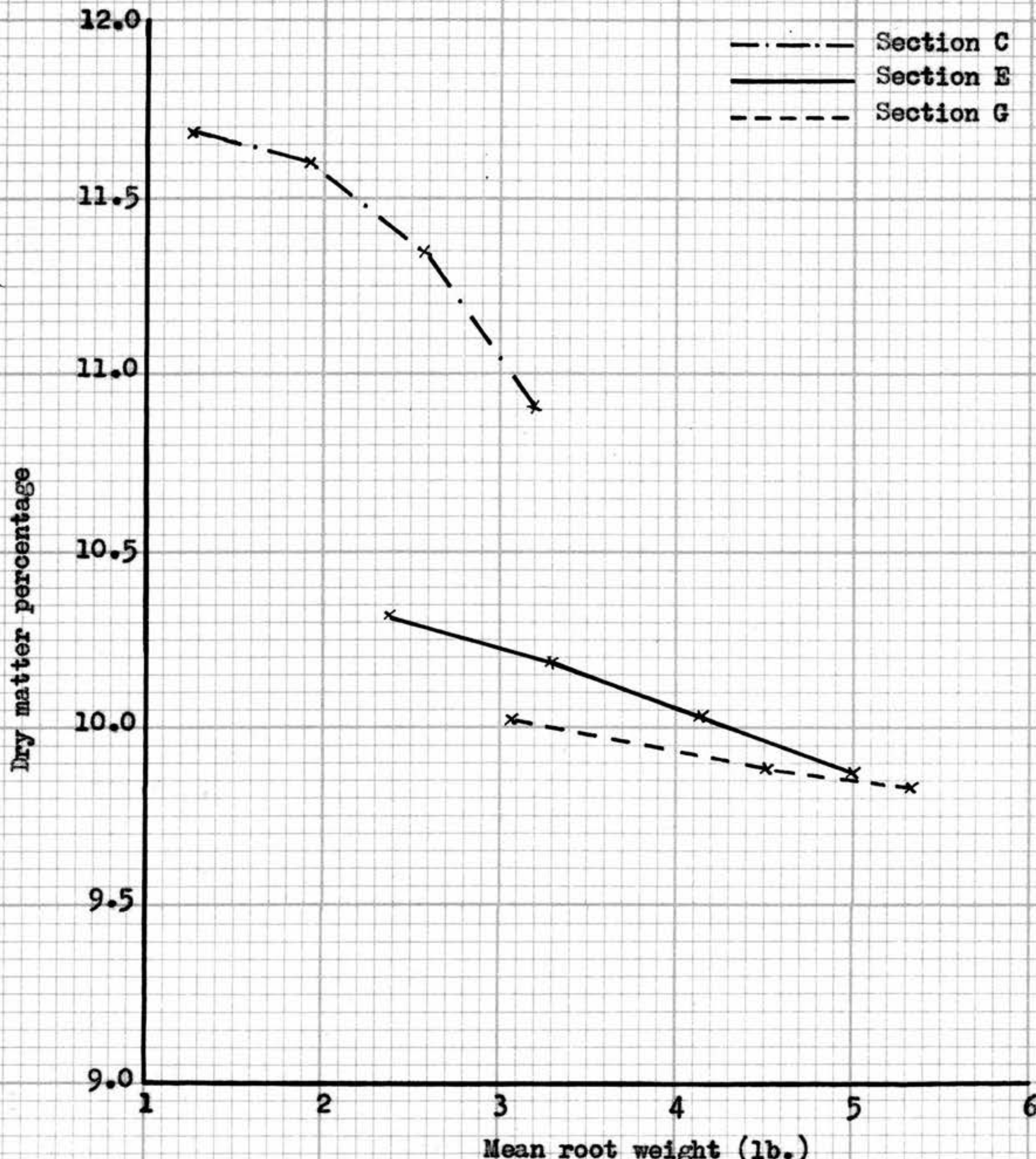


Figure 16. The effect of root size on dry matter percentage, Section C, Section E and Section G.

(1904) showed that the outside part of the swede bulb next to the skin was richer in dry matter than the inner part. In the present work, three size groups (average weights 1.6, 3.7 and 6.6 lb.) were skinned, and a dry matter determination carried out on the skin and on a vertical section cut from the 'flesh' of the root. It was found that on average, the dry matter percentage of the skin was 13.95, while the dry matter percentage of the remainder of the bulb was 11.60. This difference was highly significant. The dry matter percentage of the skin of the three sizes of bulb did not differ significantly.

If root weight is considered to be proportional to its volume, and the dry matter percentage to be dependent on the ratio of the skin (or outside portion beneath the skin) to the volume of the bulb, Figure 18 shows the theoretical effect of root size on dry matter percentage (assuming the bulb to be spherical). It can be seen that the curve is similar to that produced by Wood and Berry plotting dry matter percentage against root weight (Figure 17). It seems clear, therefore, that the difference in dry matter percentage between bulbs of different sizes is largely due to the high dry matter percentage of the skin and the area immediately below the skin.

It can be seen in Figure 16, however, that the dry matter percentage/root weight curve in Section C tends to level off at the upper end. It would seem that as the root becomes very small the dry matter content does not continue to rise at an increasing rate, and /

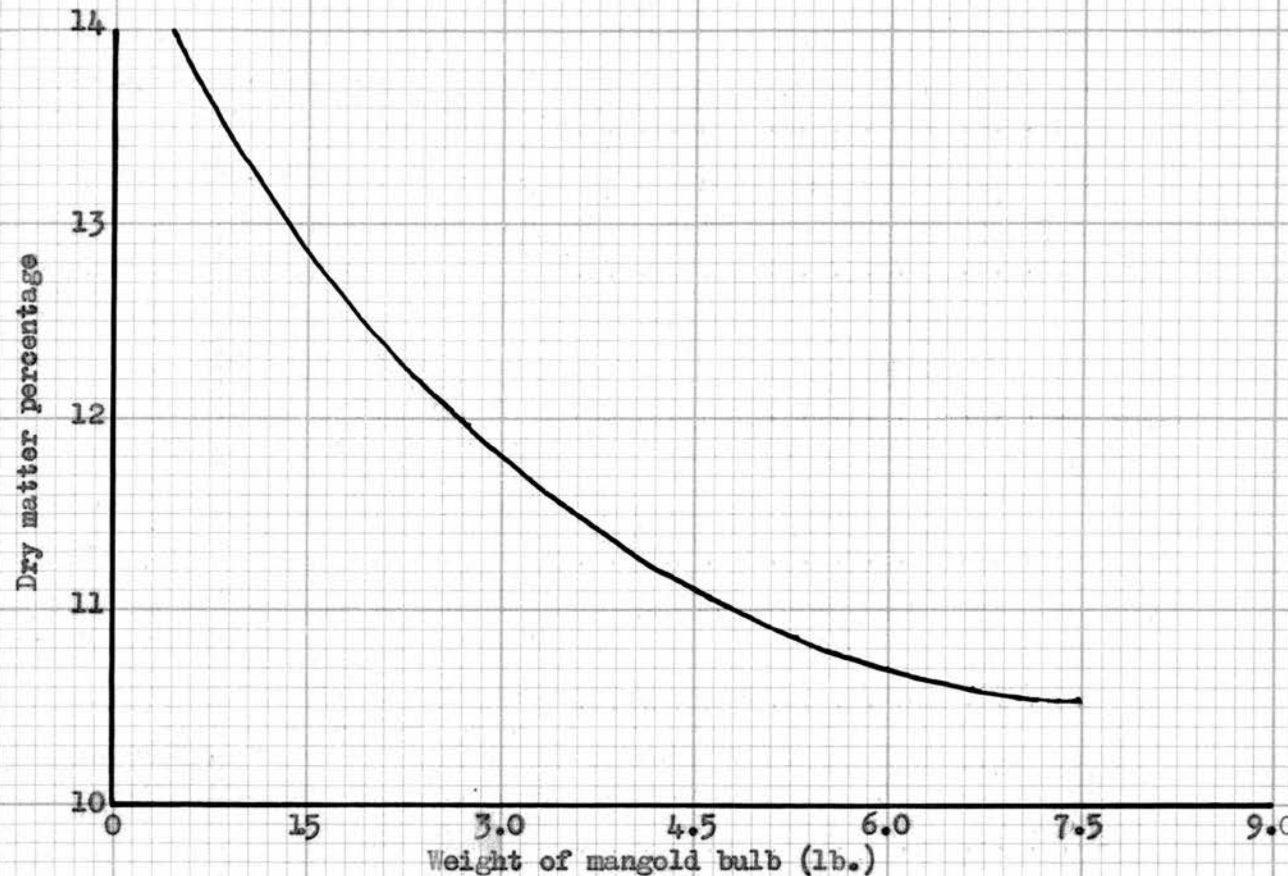


Figure 17. The effect of root weight on dry matter percentage (Wood & Berry, 1905)

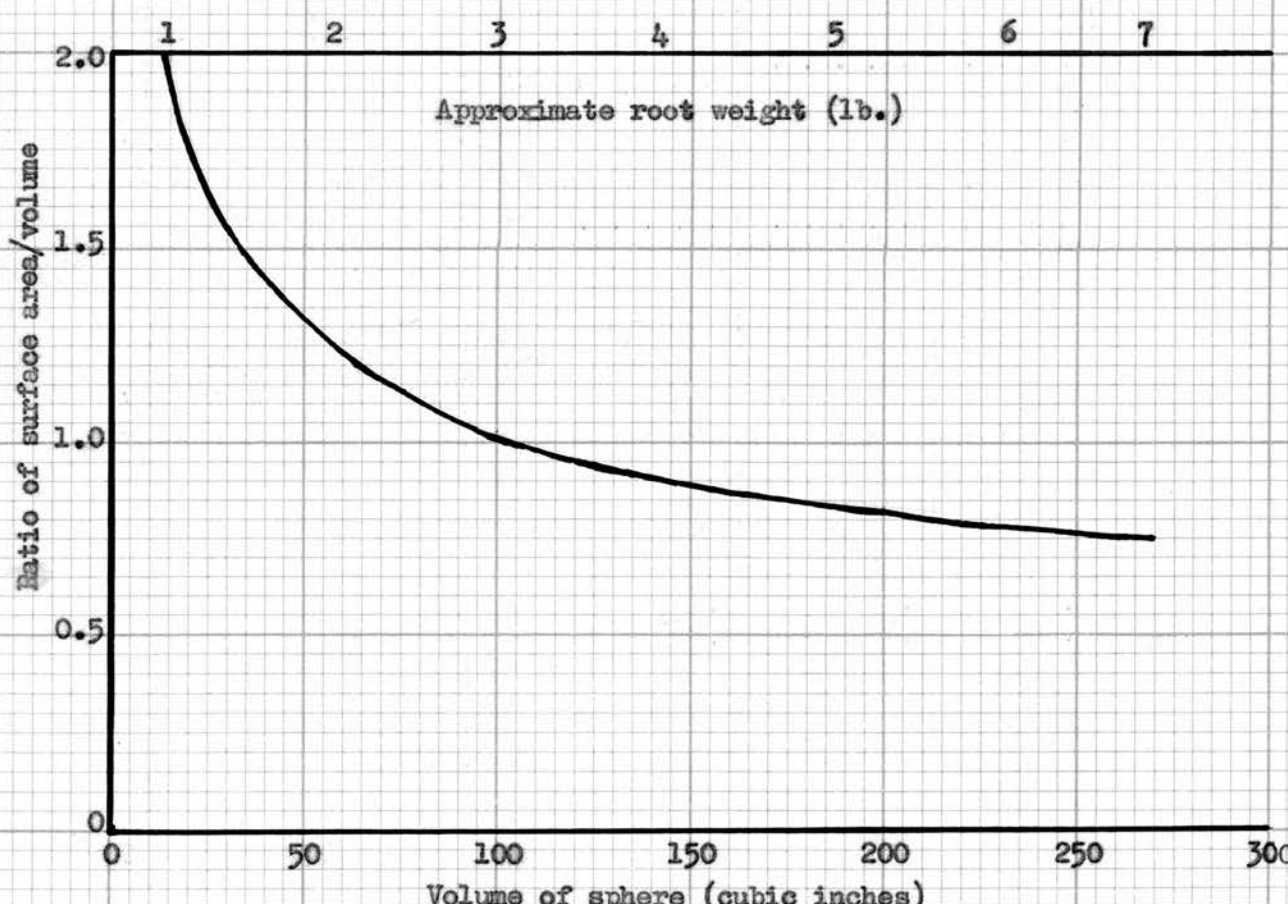


Figure 18. The volume of a sphere in relation to the ratio of surface area/volume.

and it may be that when very closely spaced, the plants tend to divert their energies from storage of food material to production of leaves. The results showed that the yield of tops was highest at the closest spacing.

There is also a suggestion from the results that the season had an effect on the dry matter percentage and on the differences in dry matter percentage between the different sized roots. Table 68 shows the range of mean plant weights, the difference between the dry matter percentage extremes, and the average dry matter percentage for each experiment.

Table 68. The range of mean plant weights, the difference between the mean dry matter percentage at the closest and widest spacing, and the average dry matter percentage for each experiment.

Section	Year	Range of mean plant weights	Difference between highest and lowest mean dry matter percentage	Mean dry matter
		lb.	per cent.	per cent.
C	1959	1.1 - 2.6	1.06	12.03
	1961	1.5 - 3.6	.43	10.77
E	1959	1.7 - 3.9	.60	10.96
	1960	3.1 - 6.1	.45	9.55
	1961	2.3 - 5.0	.35	9.77
G	1960	3.4 - 5.5	.35	10.39
	1961	2.9 - 5.2	.07	9.45

The /

The effect of plant spacing on dry matter percentage was significant in each of the experiments in 1959 ($P = .01$), and in 1960 ($P = .05$), but in the 3 experiments in 1961 (one in each section), although the dry matter percentage showed a similar trend to the previous experiments, the effect of plant spacing was non-significant, and the differences in dry matter percentage between the different sized roots in this year were smaller than in the previous years. This smaller difference in dry matter percentage in 1961 coincided with a low average dry matter percentage. Although variety and root size must influence any comparison of dry matter percentage between the years, it does appear as if low dry matter was characteristic of the 1961 season. This agrees with observations made by Wood and Berry (1905) with mangolds and Anon (1905) with swedes. These workers found that, generally speaking, a wet season produced roots of low dry matter, and a dry one, roots of high dry matter. The figures in Table 68 do suggest, therefore, that where low dry matter is a seasonal effect, as well as an effect of large root size, variations in dry matter percentage due to differences in root size are smaller than where the average dry matter is high due to season.

<u>Yield of tops</u>: The mean effect of spacing on the yield of tops in Section C and E is shown in Figure 19. This shows that the yield of tops decreased as the plant population decreased. In Section C, the effect of spacing on the yield of tops was significant at the 1% level, and just failed to reach significance in 1961. On average, 5-inch spacing /

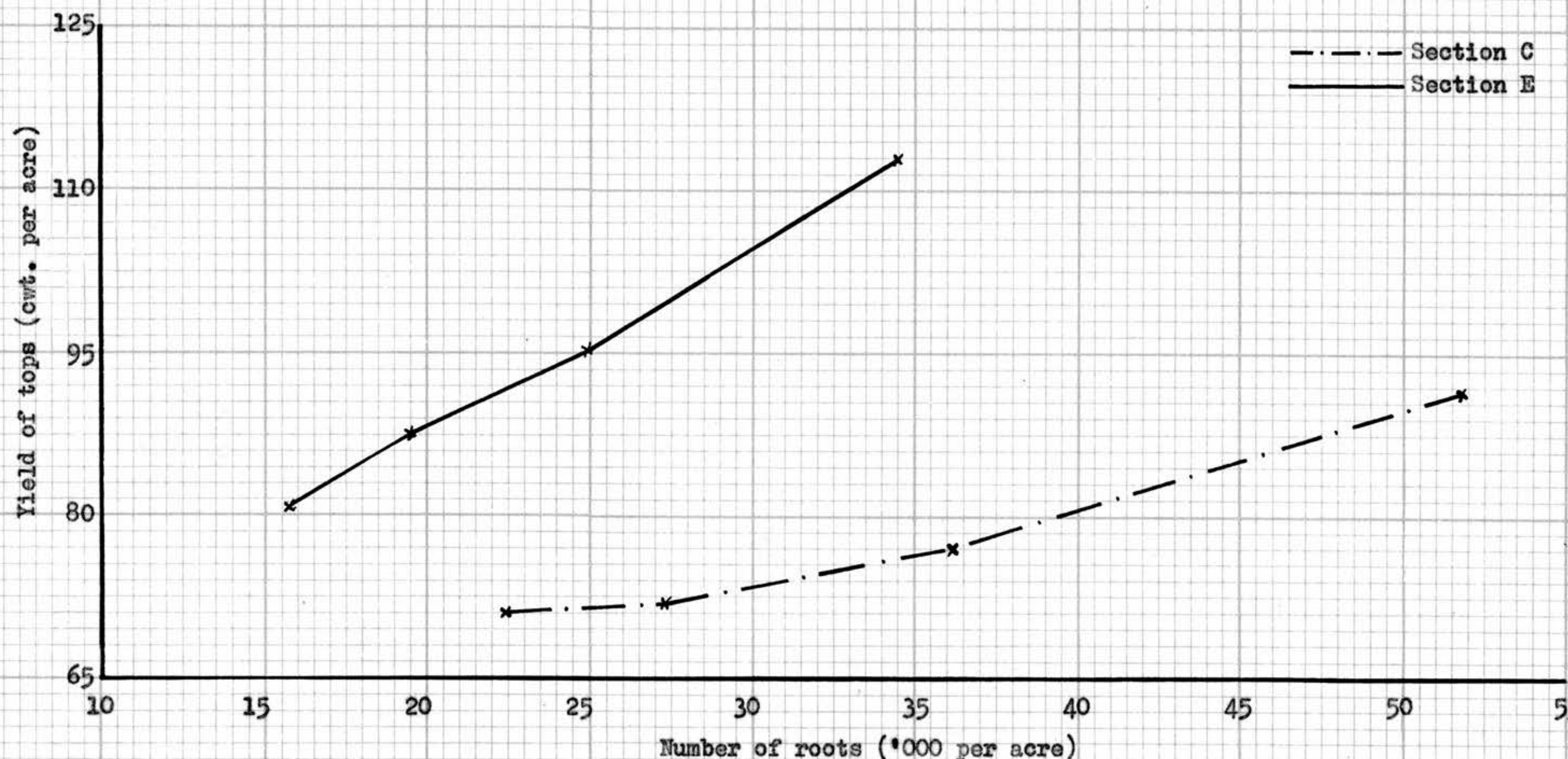


Figure 19. The mean effect of plant population on the yield of tops, Section C and Section E.

spacing produced 29% more tops than 14-inch spacing. In Section E the effect of spacing on top yield was significant in 1959, 1960 ($P = .01$) and 1961 ($P = .05$), and on average the top yield at 5-inch spacing was 39% higher than at 14-inch spacing.

Little significance can be attached to the tendency of the lower line on the graph (Figure 19) to level off at low populations, for it would be anticipated that any change in direction of the yield/population graph at low population would be downwards. The yield/population graphs within the range of populations studied would appear to be virtually straight lines, so that any increase in population is accompanied by an approximately proportional increase in top yield. Since the root yield/population graph is virtually a straight line, it follows that the root/top ratio increases as the spacing increases. Warne (1953) obtained similar results with garden beet.

Discussion:

The experiments showed that apart from the effect of disease, there was no significant difference in the yield of roots between populations of 14,500 and 53,000. It is difficult to assess the results of previous population studies, firstly because the disease factor is either not considered, or it is not known i~~n~~ the final fl yields include diseased material, and secondly, because most of the work was carried out before statistical techniques were employed.

In some early experiments (Anon - 1906) which gave an average

yield /

yield of nearly half that obtained in the present trials, populations of 15,419 and 12,860 gave 0.8 tons per acre, and 2.1 tons per acre less respectively, than a population of 27,376. The very small differences in yield between 27,376 and 15,419 agree fairly well with the present results. The experiments at Kilmarnock (Anon - 1929) showed no loss in yield at 12-inch spacing compared to 8-inch spacing in 27-inch rows. On the other hand, more recent work by Whitehead (1935) showed an average loss of $1\frac{1}{4}$ tons of roots per acre at 14-inch spacing compared to 8-inch spacing, though the effect of population on crop yield was significant in only one of the two experiments carried out. The average yield in Whitehead's experiments was approximately 23 tons per acre.

It may be that differences in the results of the various population studies are due in part to the effect of environment, particularly the fertility level. It has been suggested that lower populations might be justified at higher fertility than at low fertility, but the evidence in the literature is contradictory. The asymptotic relationship of yield and population obtained by Holliday (1960) and other workers (Roebuck - 1959, Saunt - 1960, Hunter-Smith and Rhys-Williams - 1927, Engledow et al - 1928) implies that where the 'apparent' maximum yield per plant increases as a result of increased environmental resources, the asymptote is reached as a lower population. Donald's (1951) work with Wimmera ryegrass and the work at Leeds University with kale and rape (Holliday - 1960) tend to support this hypothesis.

In /

In a series of Dutch experiments considered by Boyle (1952) soil type was found to have a definite effect on the response of fodder beet yields to different plant spacings. As the population decreased, the yield of roots on fertile soils decreased relatively less than that of plants growing on poor soils, and the yield responses to population were lower on clay than on fertile sandy soils. On fertile soils, widely spaced plants made better early growth than those similarly spaced on poor soils, thus compensating for what otherwise would have been low yields if the weight of individual roots had been the same for all spacings. Boyle also reviewed some Danish work with fodder beet, and the results failed to indicate the existence of a significant interaction between plant spacing and manurial treatment. In Bulletin 153 of the Ministry of Agriculture, Fisheries and Food (1953) it is stated that plant numbers are more necessary on poor than on good land, and in dry as compared with wet districts. On good land in high fertility, or in wet districts or seasons, all of which are conducive to rapid and continued growth, a smaller number than the recommended 30,000 sugar beet plants would suffice. This is contradicted in a further part of the same publication where it suggests that large populations are as necessary for large yields on good soils as on poor soils. Associated with the influence of fertility on the population effect, is the influence of soil moisture. Garner and Saunders (1939) studied the effect of missing plants in the sugar bee t crop and found that in a dry year, the roots immediately surrounding a gap compensated to /

to the extent of 80 to 90% for the missing plant; in a wet year compensation was less, amounting to 41 to 84% under various spacing treatments. They concluded that gaps would reduce yield to a greater extent in soils with a high water table than on others. Further studies on this aspect of populations seem justified.

The results have shown that at a high level of fertility at least, there was no loss in potential root yield within the population range 14,500 to 53,000 plants per acre, and even where quite considerable irregularity of plant distribution occurred at the widest spacing, subsequent yield losses were small. This demonstrates a useful versatility of the swede crop and shows that there need not be over-preoccupation in maintaining high population levels at very even spacing, but several factors combine to suggest that low plant populations should be avoided:-

(a) Yield of dry matter: The total yield of dry matter fell as the population decreased (Figure 20), and it can be seen that there has evolved a typical asymptotic curve similar to that obtained by Holliday (1960) and other workers. This is characteristic of yields that are some product of growth in the vegetative state, that is, a curve which rises at a diminishing rate and becomes parallel to the base axis. The asymptotic type of curve produced in Figure 20 is largely a result of the inverse relationship of root size and dry matter percentage, and owes little /

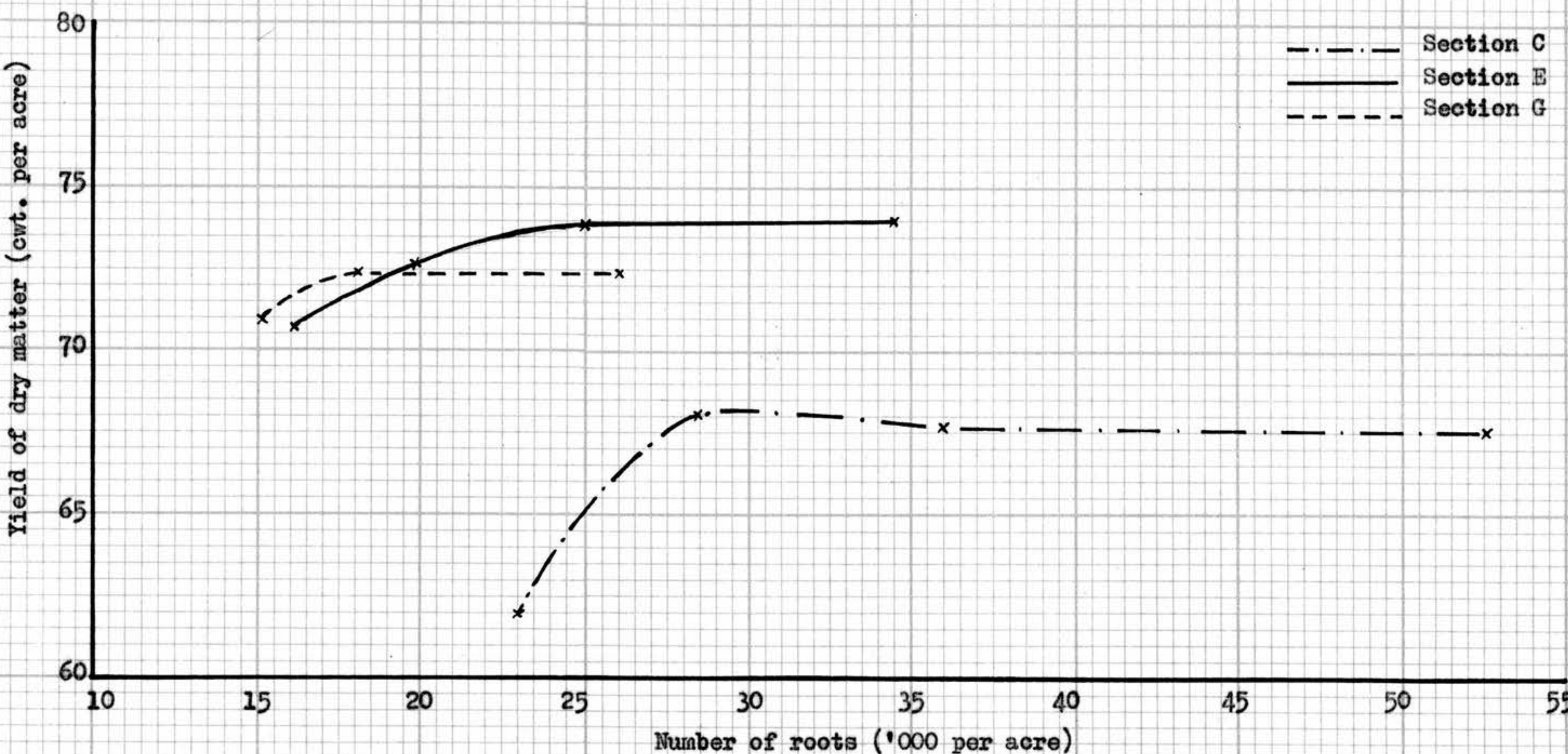


Figure 20. The mean effect of plant population on the total yield of dry matter, Section C, Section E and Section G.

little to differences in the total weight of fresh roots for which the point of inversion was not reached. As pointed out in Section H, however, the loss in dry matter yield at the wider spacings due to the lower dry matter percentage of the large roots, tends to exaggerate the loss of food value. It has been shown that approximately half the dry matter yield represented by the difference in the dry matter percentage of roots of different sizes is indigestible.

(b) Disease: The high incidence of bacterial rots in the widely spaced plants was shown to have been largely a result of splitting, and although no mention of splitting is made in the literatire, there is considerable evidence to show that disease incidence is highest in the widest spaced roots. Neil (1929) and Levy (1922) showed that dry rot (*Phoma lingam*) was most easily spread when plants were widely spaced, and attributed this to the fact that the denser leaf cover of the closely spaced plants prevented or restricted the spread of disease by splashing rain. Whitehead (1935), investigating /

that the loss in dry matter yield between the lowest and highest populationswas greatest in Section C. This is only to be expected in view of the effect of root size on dry matter percentage already discussed in the results, that is, that the smaller the average root size, the greater is the difference in dry matter percentage between different sized roots. It follows that the higher the population range studied, the greater will be the difference between the dry matter percentage extremes (other factors such as fertility and seasonal effects being equal) and the greater the loss in dry matter yield due to the different size of the roots. As pointed out in Section H, however, the loss in dry matter yield at the wider spacings due to the lower dry matter percentage of the large roots, tends to exaggerate the loss of food value. It has been shown that approximately half the dry matter yield represented by the difference in the dry matter percentage of roots of different sizes is indigestible.

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investigating the effect of spacing on the incidence of bacterial crown and root rot, found that both were most severe at wide spacings; in the case of dry rot, the incidence was low, but the disease was found only on the most widely spaced plants. Davis (1931) found no connection between the 'many-necked' condition and the incidence of bacterial rots. It may have been that the roots examined by Davis were small and, therefore, not susceptible to splitting across the crown, for the present experiments have shown that the 'many-necked' condition can be a predisposing factor to bacterial rots where the 'many-necks' have caused the roots to split across the crown.

(c) Yield of tops: Swede tops are similar to the roots in digestible crude protein and digestible fibre, but are lower in digestible carbohydrate. They contain 72% of the T.D.N. (total digestible nutrients) contained in the same weight of roots. The higher yield of tops at close spacing is of some advantage where the crop has to be grazed off in the early winter months by sheep. In Section E, the 5-inch spacing gave an increase of 1.6 tons of tops per acre over 14-inch spacing, which is equivalent in T.D.N. to approximately 1 ton of roots.

(d) Irregular spacing: The experiments have shown that little loss in yield is incurred by irregular plant distribution, though loss tended to be greater at 16-inch mean spacing than at 8- or 12-inch mean spacing. Nevertheless, Robertson (1960) stated that irregular spacing /

spacing or gaps in the plant stand are detrimental to efficient mechanical harvesting. Maughan, Wood and Chittey (1959) found that the irregular plant stand remaining on machine-thinned plots which were subsequently trimmed, as opposed to those only mechanically thinned, produced a lower standard of mechanical topping and an increase in the weight of beet left in the field by the harvester. Irregular plant distribution is, therefore, undesirable where mechanical harvesting is intended, although a considerable degree of irregularity can be tolerated when topping is done by hand. Where irregularity is the result of a poor braird, caused by dry soil conditions or poor tilth for example, the widest gaps are likely to occur in patches, and not in a random fashion along the crop row. In these conditions, yield losses will obviously occur.

For these several reasons it is inadvisable to allow the plant population to drop too low, even in fertile conditions. On the other hand there is little to be gained by very high populations, which serve only to raise the cost of singling, and the cost of harvesting where topping and tailing are done by hand. A plant population of 24,000 plants per acre at harvest should be aimed at in fertile conditions. Where the crop is sown on 27-inch ridges, this is obtained, in theory, by singling to 9½-inch spacing. The experiments have shown, however, that intended populations are unlikely to be achieved in practice. Even where singling was done carefully by hand, and plants were singled to 8-inch mean spacing, the actual population at harvest was /

was approximately 3,000 plants per acre less than the intended population. This was due in part, to irregularities in the braird, and to plants dying off after singling. Where a population of 24,000 plants per acre at harvest is aimed at, the intended singling distance should be $8\frac{1}{2}$ inches (equivalent, in theory, to a population of 27,000 plants per acre). In the method of sowing x time of singling experiments carried out between 1957 and 1960, in which the singling was done by the farm staff using 8-inch hoes, the number of roots per acre, averaged for the precision seeder sowing at 2-inch spacing and the turnip barrow, was just below 22,000. This represents an average spacing of $10\frac{1}{2}$ inches between the plants at harvest. The figures suggest that 7 inches might be a better hoe width if the optimum plant population is to be obtained. However, although 24,000 plants per acre at harvest has been suggested as the most desirable plant population to obtain, there is unlikely to be much loss in yield down to 20,000 plants per acre, in fertile conditions at least.

<u>Conclusions</u>:

At high fertility levels, where plants are spaced at between 5- and 16-inch spacing, the following conclusions are drawn:

(1) The total yield of roots is unlikely to be affected by differences in plant spacing, but when very irregular plant distribution occurs, similar to that produced by mechanical thinning, a small loss in yield is likely at the widest spacing.

(2) /

(2) The imcidence of disease, and the yield of diseased roots, is greater at wide spacing than at close spacing, and the yield of sound roots, therefore, tends to decrease as the plant spacing becomes wider.

(3) The dry matter percentage of swede bulbs varies inversely with their size, and the smaller the root size, the more the dry matter percentage is affected by changes in root size.

(4) The yield of dry matter decreases asymptotically as plant population decreases.

(5) The yield of tops increases proportionally as plant population increases.

(6) A plant population of 24,000 plants per acre at harvest should be aimed at, and this can be achieved by aiming to single to $8\frac{1}{2}$-inch spacing.

H. Supplementary Studies

1. Leaf length as an indication of growth.

Leaves are the chief organs of photosynthesis, and the leaf area is usually assumed to be the attribute that best measures the leaf's capacity for photosynthesis. According to Watson (1956) the efficiency of photosynthesis, that is, the rate of increase of dry weight per unit leaf area - or the Net Assimulation Rate (E) - was not a constant, and was not the best determinant of yield. He considered that leaf area was more important in this respect and that the best measure of the size of a photosynthetic system was the Leaf Area Index (L) which is the sum of the areas of all the leaf laminae per unit area of land. A comparison between five varieties of potatoes and three varieties of sugar beet showed that the high yielding varieties were those with the highest mean leaf area, and that there was no association of Net Assimilation Rate with high yield.

Leaf Area determinations in the field, particularly non-destructive methods, are difficult and laborious to carry out (Milthorpe - 1956). An attempt was made, therefore, to associate the area of a swede leaf with an easily determinable attribute, namely, its length, and also to associate the total leaf area of a plant with the length of the first foliage leaf.

Leaf length and area determinations were made in the experiment /

experiment designed to examine the growth rate of plants from different sizes of seed, and described in detail on page 66 . Leaf areas and the length of the leaves were measured at four stages of growth, but only three stages of growth could be used in length/area correlations because of pigeon damage after the third measurement had been made, when about 20-30% of the leaf area was eaten away. The first measurement was made just before singling when the plants had approximately 2 rough leaves, the second measurement, a week after singling, and the third measurement two weeks after singling. Cotyledon areas were included in determination of total leaf area.

Results:

The covariance analyses of the length of the first foliage leaf and its area and the length of the first foliage leaf and the total leaf area of the plant are shown in Table 69 and Table 70 respectively, while the corresponding relationships are shown in Figure 21 and Figure 22 respectively.

The length of the first foliage leaf shows a high degree or correlation with its area and a similar degree of correlation with the leaf area of the whole plant, the correlation coefficients being .82 and .80 respectively - both significant at the 1% level. The coefficients of linear regression were also significant at the 1% level and the linear regression equations were:

(a) $Y = -2.25 + 1.79X$

where Y = the expected area of the first foliage leaf and X = the length of the first foliage leaf.

(b) /

(b) $Y = -6.50 + 5.26X$

where Y = the expected total leaf area of the plant

and X = the length of the first foliage leaf.

Discussion and Conclusions:

(i) Since a high degree of correlation exists between the length of the first foliage leaf and the total leaf area of the plant, the former measurement can be regarded as a satisfactory method of growth comparison in young swede plants growing in similar ecological conditions.

(ii) In the experiment, or in similar conditions, the leaf area of a plant up to the 6-rough leaf stage approximately can be estimated from the equation $Y = -6.50 + 5.26X$, where Y = the expected total leaf area of the plant and X = the length of the first foliage leaf. It cannot be assumed, however, that this equation would have universal application to swede plants since the regression of length on area is probably influenced by such factors as plant spacing, manuring and weather.

Table 69. Covariance Analysis. The length of the first foliage leaf and its area measured at three stages of growth.

Source	d.f.	S.S. and S.P.		
		x^2	xy	y^2
Total	53	70.0791	128.2717	248.2954
Block	5	1.0224	1.6121	3.2579
Size	2	3.0263	6.4871	13.9071
Date	2	57.4044	102.7400	184.2566
Date x Size	4	0.8872	1.7108	4.4818
Error	40	8.7612	15.7217	42.3920

$$b^2 = \frac{15.7217^2}{8.7612} \text{ with 1 d.f.} = 28.23$$

$$d^2 = 42.39 - 28.23 = 14.16 \text{ with 39 d.f.}$$

$$\therefore \text{M.S.} = 0.36$$

$$\text{V.R.} = \frac{28.23}{.36} = 78.41^{**}$$

$$b = 1.79 \;;\quad r = \frac{15.7217}{\sqrt{8.7612 \times 42.3920}} = .816^{**}$$

Table 70. Covariance Analysis. The length of the first foliage leaf and the total leaf area of the plant measured at three stages of growth.

Source	d.f.	S.S. and S.P.		
		x^2	xy	y^2
Total	53	70.0791	424.3032	2736.7594
Block	5	1.0224	5.4723	40.1087
Size	2	3.0263	19.4859	128.9380
Date	2	57.4044	346.1740	2124.9740
Date x Size	4	0.8872	7.1211	65.6211
Error	40	8.7612	46.0499	377.1176

$b^2 = \frac{46.0499^2}{8.7612}$ with 1 d.f. $= 242.04$

$d^2 = 377.1176 - 242.04 = 135.0776$ with 39 d.f.

$\therefore$ M.S. $= 3.46$

V.R. $= 69.95^{**}$

$b = 5.26$; $r = \frac{46.0499}{\sqrt{8.7612 \times 377.1176}} = .802^{**}$

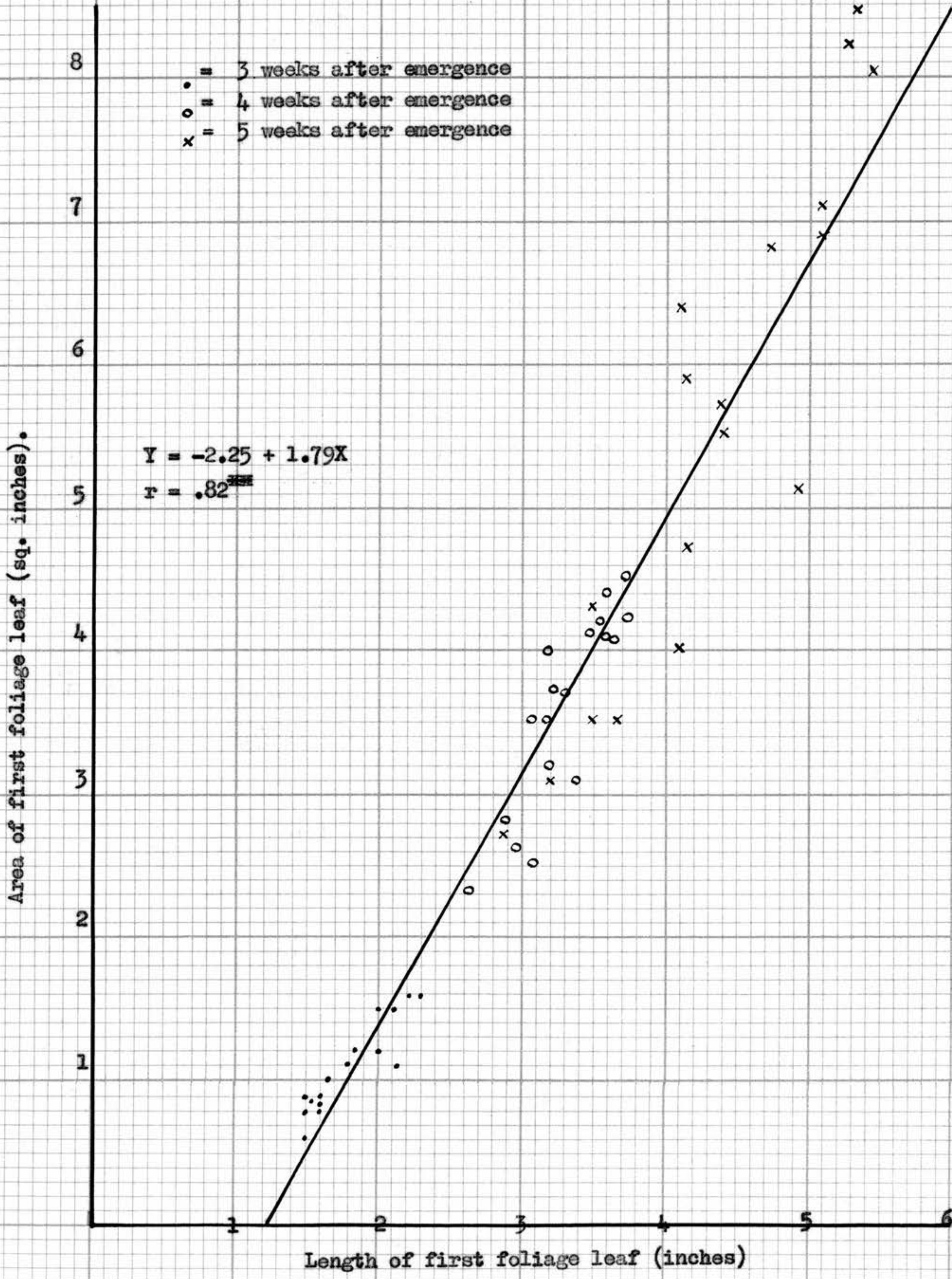

Figure 21. The relationship between the length and area of the first foliage leaf of swede plants at 3, 4 and 5 weeks after emergence.

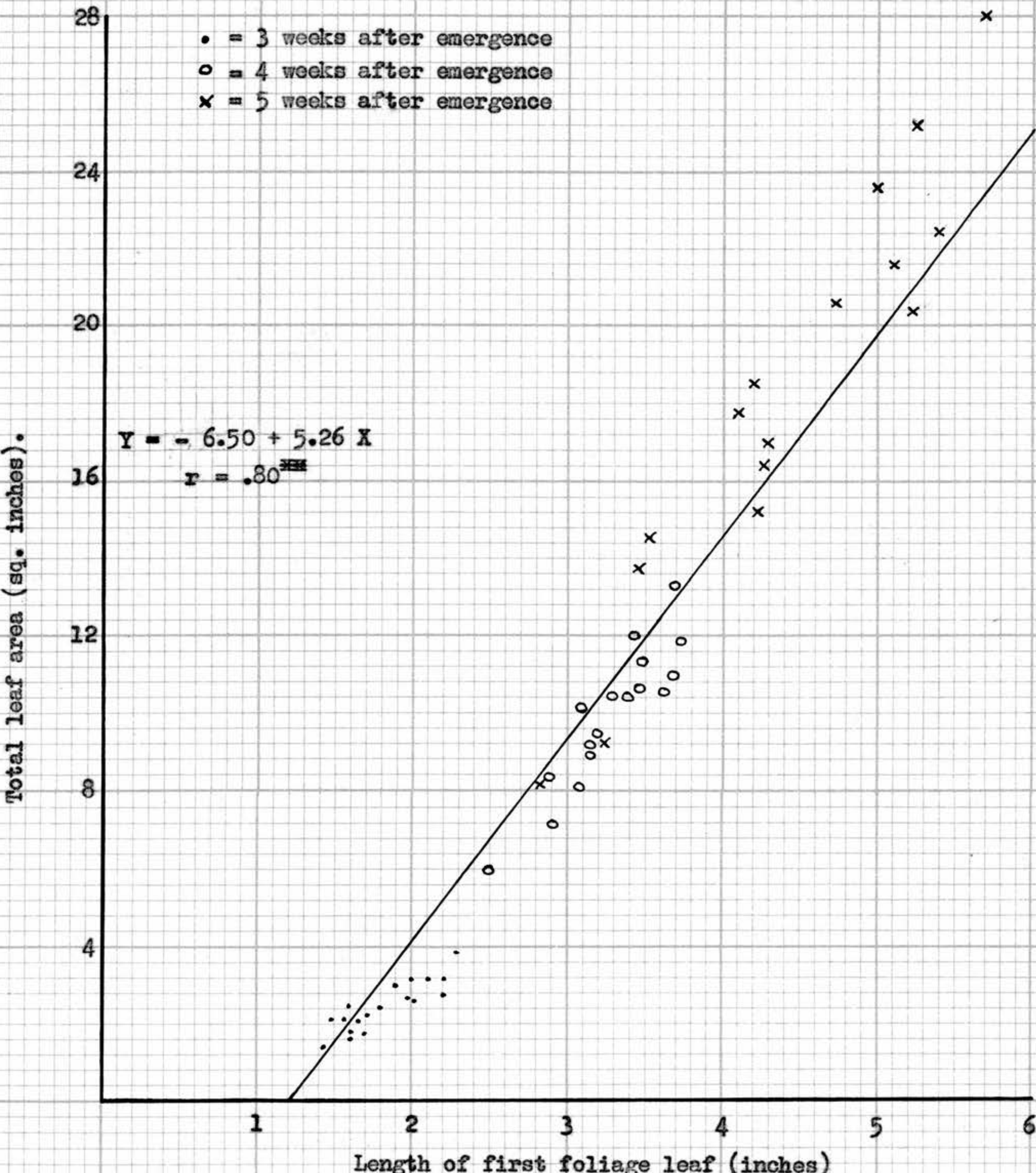

Figure 22. The relationship between the length of the first foliage leaf and the total leaf area of the plant at 3, 4 and 5 weeks after emergence.

2. Digestibility trials with sheep to ascertain the food value of the dry matter from swedes of different sizes.

This work is an adjunct to the population studies in sections C, E, and G, and its purpose was to ascertain the best meansof yield comparison in population studies, the weight of total digestible nutrients being regarded as the ultimate criterion of yield.

The trials were carried out in 1960 and 1961 with Cheviot hoggs harnessed for faeces collection. Two sizes of root were fed, and three sheep were allocated to each treatment in both years. In each of the years, one of the sheep allocated to the large roots could not be induced to eat in the digestibility crate, so that results from two sheep only were obtained each year for this treatment.

The swedes used in the trials were taken from one of the experiments in which plant spacing was a treatment, the largest and smallest roots from the widest and closest spacing treatments respectively, being selected, in order to emphasis the difference between the sizes of root fed. The variety used in both trials was Victory. The average root weights and dry matter percentages are given in Table 71.

Table 71 /

Table 71. The average weight and dry matter percentage of the large and small roots in 1960 and 1961.

Year	Large roots		Small roots	
	Average weight	Dry Matter	Average weight	Dry Matter
	lb.	per cent.	lb.	per cent.
1960	3.0	10.29	1.0	11.43
1961	7.0	8.78	1.7	8.99

The roots were carted in from the field in December and stored indoors. The first trial was carried out during the last week of January 1960, and the second one at the beginning of March 1961.

Method:

Since procedure differed only slightly in the two years, the 1961 experiment is described in detail, procedural differences in the earlier experiment being pointed out.

About ten days before the trial was due to begin, the sheep were penned indoors, fed swedes and hay for a few days before being harnessed, and then transferred to the digestibility crates where they were fed an 'all swede' diet. The swedes were removed from the clamp several days before the trial commenced, thoroughly scrubbed free from dirt in warm water and laid out to dry.

Experimental feeding commenced on the 3rd March and continued for ten days - until the 12th March; faeces collection commenced on the /

the 5th March and ended on the 14th March. The approximate daily requirements of swedes for all sheep on each of the treatments were weighed out each morning. Every swede was cored and a dry matter determination made on the bulked cores for each treatment group. The swedes were chopped, thoroughly mixed and weighed out accurately to each sheep. In 1960, the swedes for each sheep were cored and chopped separately. The feed boxes were emptied completely each morning and the individual residues stored in polythene bags. Every two days the total residue collected for each sheep was dried and weighed.

The faeces collections were transferred daily to large polythene bags (one for each sheep) which throughout the trial were kept in cold storage. When the ten-day collection period was completed, the bulked faeces from each sheep were thoroughly mixed, and a small amount weighed out for crude protein estimation. The whole of the remaining faeces was used for dry matter determination. In 1960, the fresh sample for crude protein determination was weighed out from the daily faeces collection, and dry matter determinations were also carried out on a daily basis.

Chemical analysis was carried out on a sample from the bulked dried cores and on the bulked faeces from each sheep. In 1960, the food residue was similar ~~to~~ in ~~e~~ composition to the food fed. In 1961, sheep K was very obviously selective, refusing to eat almost any of the skin. Sheep H had a similar tendency though much less noticeable /

noticeable than K. Since none of the other residues showed any signs of selective feeding, only the residues of K and H which were both appreciable in amount, were analysed. The residue of sheep K was found to differ in composition very considerably from the food fed. Although the food residue analysis can be used to give truer digestibility figures for the fractions in the food eaten, it cannot give acceptable values for the composition of the roots fed. Consequently, the results for sheep K were not taken into consideration in the final analysis of results. The food residue of sheep H also differed in composition from the food fed - but to a lesser extent, and the difference here was more in the proportion of constituents making up the organic matter rather than the difference in the percentage of organic matter in the dry matter. The values for digestible nutrients for sheep H were little affected when corrected for the composition of the residue, as also were the values for S.E. (starch equivalent) and T.D.N. (total digestible nutrients). The latter values were in fact slightly raised by correcting for the food residue, thereby coming even closer to those values for sheep G on the same treatment. The residue for sheep G was very small in amount, being only 4% of the food fed. The corrected values for sheep H are used in the statistical analysis of the S.E. and T.D.N. The composition of the residues of sheep K and H are given in Appendix C, Table 310.

<u>Results:</u>

Tables /

Table 72 and 73 give the mean percentage composition of the dry matter and the mean digestible nutrients (percent of dry matter) of the large and small roots in 1960 and 1961, respectively, while Tables 74 and 75 give the S.E. and T.D.N., respectively, for the individual animals in both experiments. The calculation of the digestibility coefficients, the digestible nutrients for individual sheep, and the composition of the residues, is given in Appendix C, Table 306 to 310.

The S.E. and T.D.N. were calculated as follows:-

$$S.E. = (dig.C.P. \times .94) + (dig.E.E. \times 1.9) + dig.C.F. + dig.N.F.E., \times \frac{85}{100}$$

$$T.D.N. = dig.C.P. + (dig.E.E. \times 2.25) + dig.C.F. + dig.N.F.E.$$

It can be seen from Tables 74 and 75 that the S.E. and T.D.N. of the small roots were consistently lower than for the large roots, and this treatment difference both for S.E. and T.D.N., was significant at the 5% level of probability.

A study of Table 72 and Table 73 shows that the composition of the dry matter of the large and small roots did not differ markedly, except in crude fibre which was 8% higher for the small roots. The main difference between the roots of different sizes was in the percentage of digestible nutrients in the dry matter - particularly in 1960. In that year, the lower S.E. and T.D.N. values of the small roots were due to lower digestible crude protein, digestible crude fibre and digestible nitrogen-free extract. This pattern cannot be distinguished in 1961 when the digestible organic matter of /

Table 72. Mean percentage composition of the dry matter, and the mean percentage digestible nutrients in the dry matter, of the large and small roots in 1960.

	Large roots		Small roots	
	Mean percentage composition of the dry matter	Mean percentage digestible nutrients in the dry matter	Mean percentage composition of the dry matter	Mean percentage digestible nutrients in the dry matter
Organic matter	93.73	84.80	94.63	80.12
Crude protein	8.45	5.45	7.08	2.95
Ether extract	0.58	0.27	0.61	0.23
Crude fibre	11.20	9.01	12.74	7.82
Nitrogen free extract	73.51	70.11	74.19	68.92

Table 73. Mean percentage composition of the dry matter, and the mean percentage digestible nutrients in the dry matter, of the large and small roots in 1961.

	Large roots		Small roots	
	Mean percentage composition of the dry matter	Mean percentage digestible nutrients in the dry matter	Mean percentage composition of the dry matter	Mean percentage digestible nutrients in the dry matter
Organic matter	93.14	85.01	93.33	84.18
Crude protein	12.00	8.99	12.25	9.09
Ether extract	0.72	0.45	0.63	0.31
Crude fibre	10.65	8.51	11.35	9.03
Nitrogen free extract	69.77	66.88	69.10	65.73

Table 74. Starch Equivalent, 1960 and 1961.

Year	Sheep	Large Roots	Sheep	Small Roots
1960	T	73.89	P	67.74
	U	70.12	Q	67.56
			R	68.65
	Mean	72.01		67.98
1961	G	72.65	F	71.19
	H	72.05	L	71.44
	Mean	72.35		71.31
Mean		72.18		69.65

<u>Analysis of Variance</u>

Source	d.f.	SS	MS	VR
Total	8	39.6356		
Years	1	11.1552	11.1552	6.97
Root Size	1	18.1959	18.1959	11.37*
Root Size x Years	1	2.2839	2.2839	
Error	5	8.0006	1.6001	

S.E. of treatment mean = $\pm$ 0.60

Table 75. Total Digestible Nutrients, 1960 and 1961.

Year	Sheep	Large Roots	Sheep	Small Roots
1960	T	87.38	P	79.90
	U	82.87	Q	79.74
			R	81.06
	Mean	85.72		80.23
1961	G	85.72	F	84.01
	H	85.46	L	84.69
	Mean	85.59		84.35
Mean		85.36		82.29

<u>Analysis of Variance</u>

Source	d.f.	SS	MS	VR
Total	8	59.5466		
Years	1	18.4961	18.4961	8.20*
Root Size	1	26.4444	26.4444	11.73*
Root Size x Years	1	3.3306	3.3306	
Error	5	11.2755	2.2551	

S.E. of treatment mean = $\pm$ 0.75

of the large and small roots differed by only 0.8 unit %. Although the resulting differences in S.E. and T.D.N. are very small in 1961, they are in the same direction as in 1960, and when considered with them, give an overall significant effect.

It can be seen in Table 71 that the difference in dry matter percentage between the two sizes of roots was much greater in 1960 than in 1961. This was probably due in part to the small average size of the roots in the first experiment. Wood and Berry (1905) with mangolds, found that small changes in weight made a larger difference in the dry matter percentage of small roots than in that of large roots, and the population studies in the present experiments confirm this. Respiration losses during storage also probably contributed to the small difference in dry matter percentage in 1961, since the storage period was much longer for the second experiment, and it is conceivable that respiration losses were greater in the small roots than in the large, which weight for weight have a smaller surface area. This is borne out by the fact that the dry matter percentages of the largest and smallest root groups in the field were 9.33 and 9.78 respectively, and after selection from these groups and a three month storage period, the dry matter percentages were 8.78 and 8.99 respectively. (Respiration losses in swedes during storage has been studied by Voelcker - 1877, Larsen - 1901, and McCandlish - 1931). This small difference in dry matter percentage between the two sizes of root in 1961 compared to 1960, coincides with /

with a smaller treatment difference in S.E. and T.D.N. values.

Yields from different populations can be compared on a fresh or dry weight basis. The two sizes of roots in 1960 and 1961 were therefore compared on a fresh and dry weight basis on the assumption that the T.D.N. gives the true value of the crop. The T.D.N. in 100 lb. of fresh roots was obtained from the product of the weight of dry matter in the 100 lb. of fresh roots and the T.D.N. content of the dry matter.

1960

(a) Comparison on fresh weight basis.

T.D.N. in 100 lb. small roots $= 11.43 \times \frac{80.21}{100} = 9.17$ lb.

T.D.N. in 100 lb. large roots $= 10.29 \times \frac{85.13}{100} = 8.76$ lb.

$\therefore$ the weight of large roots equivalent in T.D.N. to 100 lb. small roots

$$= \frac{100 \times 9.17}{8.76}$$

$$= 104.7 \text{ lb.}$$

(b) Comparison on dry weight basis.

T.D.N. in 100 lb. dry matter from the small roots $= 80.21$ lb.

T.D.N. in 100 lb. dry matter from the large roots $= 85.13$ lb.

$\therefore$ the weight of dry matter from the large roots equivalent in T.D.N. to 100 lb. dry matter from the small roots $= \frac{100 \times 80.21}{85.13}$

$$= 94.2 \text{ lb.}$$

1961 /

1961

(a) Comparison on fresh weight basis.

T.D.N. in 100 lb. small roots $= 8.99 \times \frac{84.56}{100} = 7.6$ lb.

T.D.N. in 100 lb. large roots $= 8.78 \times \frac{85.59}{100} = 7.5$ lb.

.˙. the weight of large roots equivalent in T.D.N. to 100 lb. small roots

$$= \frac{100 \times 7.6}{7.5}$$

$$= 101.3 \text{ lb.}$$

(b) Comparison on dry weight basis.

T.D.N. in 100 lb. dry matter from the small roots = 84.56 lb.

T.D.N. in 100 lb. dry matter from the large roots = 85.59 lb.

.˙. the weight of dry matter from the large roots equivalent in T.D.N. to 100 lb. dry matter from the small roots $= \frac{100 \times 84.56}{85.59}$

$$= 98.8 \text{ lb.}$$

It can be seen from the calculations that in comparing the different sizes of root on a fresh weight basis, the T.D.N. is overestimated with the large roots and underestimated to approximately the same extent with the small roots; in comparing yields of dry matter, the reverse is the case. Averaging the results of the two years, a comparison of the large roots with the small, on a dry weight basis, underestimates the yield of T.D.N. in the fresh roots by 3.5%; comparison on a fresh weight basis overestimates the yield of T.D.N. in the fresh roots by 3.0%

In comparing the dry matter yields of roots of two sizes, therefore /

therefore, the difference in size being due to a difference in plant population, the yield of T.D.N. from the large roots is underestimated by a weight of dry matter equal to approximately half of that represented by the difference in dry matter percentage between the two sizes of root.

Variations in composition: It is interesting to note the quite considerable difference in composition between the roots used in the two experiments (Table 72 and Table 73). Although no direct comparison can be made between the two years since too many variables exist, the figures do show the composition differences that can occur within a variety. Some of the factors affecting the composition of the swede are discussed by Collins (1905) and Lauder (1926). There was a difference of 2% in the average dry matter percentage between the roots used in the two experiments and although this can be partly explained by the difference in average root size and by respiration losses, it is undoubtedly partly a seasonal effect. The composition of the dry matter also varied considerably. On the average of the two size groups, crude protein was lower in 1960 by approximately 4%, the nitrogen-free extract was 4% higher, and statistical analysis of the T.D.N. (Table 75) shows that the difference in T.D.N. between the two years was significant at the 5% level.

Dodsworth (1956) drew attention to the fact that the composition of swedes which he used in experiments with beef cattle was considerably different from that given by Woodman (1952). Dodsworth's T.D.N. and S.E. /

S.E. values were higher than those of Woodman, and Dodsworth believed this was a climatic effect, which confirmed the opinion of Lauder that swedes grown in the North have a higher feeding value than those grown in the South. The S.E. and T.D.N. obtained in the present experiments are compared with those of Woodman, and Dodsworth, in Table 76.

Table 76. A comparison of the S.E. and T.D.N. obtained, with those of Dodsworth (1956) and Woodman (1952).

	S.E.	T.D.N.
Average of large and small roots, 1960	70.0	82.7
Average of large and small roots, 1961	70.9	83.8
Dodsworth (1956)	73.9	87.3
Woodman (1952)	63.5[x]	81.8

[x]calculated on a digestible true protein basis.

The S.E. given by Woodman is calculated from digestible true protein. Calculated on a digestible crude protein basis, Woodman's S.E. is 69.0. This does not appear to have been taken into account by Dodsworth in his appraisal of Woodman's figures, Dodsworth's S.E. having been calculated on a digestible crude protein basis. It can be seen that the S.E. and T.D.N. obtained in the present experiments agree closely with those of Woodman. Woodman's corrected figures would appear to be quite satisfactory for East of Scotland conditions at least.

V. GENERAL DISCUSSION AND CONCLUSIONS

There have been two main avenues of approach to the question of reducing the labour costs incurred in the production of the required plant stand in the turnip crop. Firstly, seed has been sown at 3 lb. per acre and the crop mechanically thinned once or twice, this operation usually being followed by hand trimming, and secondly, seeds have been sown singly at required intervals. Mechanical thinning does not, at present, appear to offer the best solution to the problem, and most attention, therefore, has been paid to precision seeding.

Precision seeding has undoubtedly been the greatest single step towards modernising the husbandry of root crops, and must have helped considerably in the past decade to arrest the declining acreage of turnips and swedes. As with most innovations, there have been difficulties, but the mechanical problems of precision seeding have now been solved, and some new, efficient and reliable sowing mechanisms are now on the market. Any attempt to dispense with singling in the swede crop no longer depends on finding a sowing mechanism efficient enough to sow seeds accurately and reliably at desired intervals, but on the use of seed of high germinating capacity, on sowing this seed in a good tilth with adequate moisture content, and on chemical weed control.

In the germination tests carried out in Section IV.C, average germination /

germination was high (96%) and varied from 92% to 100%. It is rather disquieting, however, to find that in the Seeds Act (1920) the specified minimum germination percentage for swede seed is 80%. Since emergence would be lower than this, it is obvious that if a seeder unit was sowing at 4-inch spacing or wider, the use of seed of the specified minimum germination standard could be most harmful to plant stand. Poor germination may result if seed is not fully ripened when harvested, if it has matured or been harvested in unfavourable weather, if it has not been stored under good conditions, or has been chemically dressed when in an unsuitable state. Most of these factors are controllable, but since weather is an important factor in determining germination capacity, stocks of seed poor in germinating capacity must almost inevitably arrive on the market. It is to be recommended that the standard below which the germination percentage of seed for sale must be declared, should be raised, or alternately, that the germination percentage of swede seed sold for precision seeding should be stated. Where a farmer proposes to precision sow at wide intervals, he would be advised to have the seed sample tested at the Official Seed Testing Station. This is to be particularly recommended for seed carried over from a previous season, and especially if the seed has been chemically treated prior to storage.

The importance of tilth for the swede crop has always been stressed. It is well known that the ground for the swede crop must /

must receive more working than for most other crops, and that on the other hand, over-working must be avoided to prevent drying-out. If the importance of tilth and soil moisture for a good braird has been emphasised in the past when seed was sown at 3 lb. per acre, these factors are much more important at the present time where precision seeding is practised. The aim might be to make 'germination' synonomous with 'emergence', but this ideal is unlikely to be achieved in practice, for apart from the influence of tilth and soil moisture, soluble fertiliser salts are likely to reduce the percentage of plants to emerge. The present experiments have shown, however, that although broadcasting fertiliser before ridging is likely to reduce emergence percentage, the effect on plant stand is likely to be small unless the fertiliser is applied considerably in excess of recommended levels.

The present work has shown that it is inadvisable to ignore the effect of inter-plant weeds on crop yield, and if sowing at wide intervals is carried out, some form of weed control is necessary. Although it has been shown that in conditions of good fertility and adequate rainfall, where weed infestation was not severe, little loss in yield might be incurred by leaving inter-plant weeds in the crop, the procedure cannot be adopted as a practice. It can only be regarded as a useful expedient where labour is in short supply and the weeds are not troublesome, as may be the case when the crop follows a ley. The use of pre-emergence sprays in the swede crop is /

is still very much in the experimental stages, but one or two products are coming on to the market and are showing considerable promise of success. It must be some time, however, before the use of pre-emergence sprays becomes widespread, so that hoeing or singling by hand, and mechanical inter-row cultivation must remain necessary operations for the time being.

In addition to using seed of high germination capacity with the precision seeder, the full advantages of precision seeding can only be obtained if the largest seed of the chosen variety is used. The experiments have shown that there isevery justification for raising the level at which graded seed is removed from the bulk sample for precision seeding. A small yield advantage is likely to be obtained by doing so - and this without any additional cost.

The stage of growth at which singling is carried out does not appear to be critical in the swede crop. If necessary, singling can be spread over a considerable period (2- to 6-leaf stage) with little loss in yield occurring. Singling too early should be avoided since this tends to reduce plant numbers, but early singling, in general, is to be recommended, for apart from any small yield advantage, the operation takes less time (particularly if the crop has been sown with the turnip barrow). In addition, there is a tendency to leave the plants more erect when they are small at singling. Couping the plants at singling tends to reduce plant numbers and crop yield, and greatly increases the number of plants growing /

growing prostrate at maturity, which is very undesirable if the crop has to be harvested mechanically. Every effort, therefore, should be made to leave the plants erect at singling. Plants can be singled, and the inter-plant spaces cleaned quite efficiently without deliberately couping the plants over, and this is particularly true where the crop is precision sown. It is generally not possible to wait for ideal conditions at singling, but where possible, singling in very dry conditions should be avoided, as the plants tend to receive a greater check than when singled in moist conditions.

It is clear that there need be no over-preoccupation with maintaining very high plant populations at very even spacing. In fertile conditions, the crop can tolerate a wide range of populations at a considerable degree of irregular distribution. Populations below 20,000 plants per acre at harvest should be avoided, and the optimum would appear to be about 24,000 plants per acre at harvest. It may be, however, that in less fertile conditions, the optimum population is higher than 24,000 plants per acre. To ensure this population level, the aim should be to single the plants to 8½-inch spacing, which is equivalent, in theory, to a population of 27,000, and the use of a 7-inch hoe is, therefore, recommended. Apart from the effect of population on dry matter yield, and to a less extent, the effect on the yield of tops, avoidance of low populations reduces disease incidence. This may have more far-reaching effects than the effect on the yield of sound roots would indicate, since it /

it is reasonable to expect that fewer diseased roots would be pitted, with a corresponding reduction in the spread of bacterial rots in the pit.

As far as mechanical harvesting is concerned, the size of inter-plant spacings is of little consequence provided the spacing is not so close that the knife blade of the harvester cannot fall between the plants. The regularity of plant distribution, however, is of considerable importance, and where the crop has to be harvested mechanically, every effort should be made to obtain regular plant distribution. Even more important from the point of view of mechanical harvesting than the regularity of plant distribution, is the erectness of the crop. The results show that precision seeding has an advantage over the turnip barrow in this respect, and that additional rolling after sowing also tends to produce a more erect crop at harvest. Any heavy rolling should be avoided, however, since the onset of drought after rolling may be detrimental to plant growth. Probably the most important factor in determining the erectness of the crop is singling. Where plants are couped at singling, many more prostrate plants are to be found at harvest. Obviously, precision seeding at wide intervals and the omission of singling, accompanied by chemical weed control, dovetails well with efficient mechanical harvesting. It is quite possible that swedes grown on the flat may be more erect in growth habit than those grown on the ridge, but any other effects of growing on the flat would need to be considered, particularly the effect on yield.

A /

A further aid to mechanical harvesting is the selection of a suitable variety. As a result of recent work by Dr. V. McM. Davey of the Scottish Society of Plant Breeding at Pentlandfield, the variety Pentland Harvester has been officially registered in Scotland. This variety is eminently suitable for mechanical harvesting. The bulbs are relatively free from side shoots, have a good hold in the ground, and are uniform in shape. Some of the older varieties, however, are quite suitable for mechanical harvesting, and work at the North of Scotland College of Agriculture has shown that swedes of the globular semi-tankard shape are best, for example, Caledonian, XL All, Jubilee and Viking. Where mechanical harvesting is intended, the variety's suitability for this operation must be a major consideration.

At the present time, several fairly efficient machines which will 'top and tail' the turnip crop are on the market, and although there is no entirely satisfactory complete harvester, it can only be a matter of time before an efficient complete harvester is available. There have been reports of crops very successfully topped, tailed and lifted by means of a Massey-Ferguson potato harvester with only very slight modification. This suggests a possible solution to the high capital cost necessarily involved in the purchase of a complete harvester.

Returning to the question of variety, it is interesting to look at the results of swede variety trials carried out by the National /

National Institute of Agricultural Botany. These results over a number of years indicate that differences in dry matter yield generally range from around 86% to 112% of the mean. Yield of dry matter must, therefore, be a major consideration in selecting a variety. Just as important as dry matter yield, however, is winter hardiness which is associated with high dry matter content. It is very important that the way in which the crop has to be utilised is decided upon before sowing. If the crop has to remain in the ground well into the winter months, a high dry matter, late-maturing type should be chosen. To lift this type of swede early is only to incur losses in dry matter yield, and for early use, a low dry matter, early-maturing type should be chosen. Other factors to be considered are disease resistance and resistance to splitting, which has been shown to be a predisposing factor to bacterial rot.

In connection with splitting, a question worthy of further attention is the 'many-necked' condition. This has been shown to be a predisposing factor to splitting which provides access to bacterial soft rots. As previously suggested, diseased roots, or roots severely split in this way, probably increase the spread of infection in the pit. It is believed that the many-necked condition is primarily caused by the depredations of the swede midge, and the control of this pest would, therefore, be of some benefit to the crop.

One further question in relation to swede crop husbandry hitherto undiscussed, is that of sowing date. There appears to have been a tendency /

tendency in recent years to regard the sowing of the swede crop as an operation to be undertaken only when all the other spring work has been completed. When other operations have been delayed by bad weather, this means sowing swedes from the middle to the end of May - or even into June. This is unfortunate, for earliness of sowing is probably just as important for high yields with swedes as with sugar beet. Earliness of sowing is, of course, associated with bolting, but swedes are less liable to bolting than turnips, and results from the North of Scotland College of Agriculture over a 10-year period show that sowing swedes at weekly intervals from the 1st May to the 12th June was accompanied by a gradual loss in dry matter yield. In earlier experiments with swedes at Boghall farm (Edinburgh College of Agriculture) plots were sown at weekly intervals between the 23rd April and the 4th June, and the plots harvested 5 months after sowing. The earliest sowing gave 0.7% bolters, while no bolters occurred with any of the later sowing dates. The yield of roots from the earliest sowing was 35 tons per acre; sowing one week later yielded 27 tons per acre, and there was steady loss in yield until the final sowing date, when the yield of roots was 15 tons per acre. Where possible, the crop should be sown at the beginning of May, or even earlier, depending on district. After the middle of May, yield losses are likely to become severe. Early sowing is particularly important where 'club root' disease is troublesome. This disease can normally be controlled by rotation and the use of resistant varieties, such as Wilhelmsburger, but where the disease /

disease is present, its incidence is aggravated by late sowing.

The estimated yields of turnips and swedes in Scotland, and in England and Wales, averaged over the past ten years, are given in Table 2 and Table 3 respectively. Making some allowance for yields being underestimated by crop recorders, it is obvious, since many crops of 30 to 40 tons per acre are known to be grown, that some very poor crops of swedes must be included in the national averages - probably as low as 10 tons per acre, or even lower. It is difficult to understand why crops of this size are produced, provided the most elementary principles of good husbandry are adhered to. Where sufficient fertiliser is applied, where reasonable care is taken to produce a good tilth so that adequate plant numbers remain after singling, where the necessary steps are taken to control weeds, and where the right variety is sown early enough, only severe drought should be responsible for poor brairds and low yields. The low level of the national average yield of swedes and turnips calls for investigation.

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VII ACKNOWLEDGMENTS

I wish to express my appreciation to all those concerned in the completion of this project. Thanks are specially due to:

Professor S.J. Watson and Dr. J.C. Holmes for their guidance and helpful criticism,

Dr. P. McDonald and his staff without whose co-operation the digestibility trials could not have been carried out,

Dr. D.N. Lawley for his assistance with statistical problems,

the staff of the Crop Husbandry Unit for their assistance with the field work,

my wife, Norma, for her assistance with leaf area measurements and statistical analysis, and for her encouragement and support throughout,

Miss Morag MacKenzie for typing the final copy.

VII APPENDICES

APPENDIX A.

Details of Crop Cultivation

Section IVC

(The effect of seed size)

Table 77. Preceeding crop, and manuring in trial year, 1959, 1960 and 1961.

Year	Preceeding crop	Manuring
1959	Block I - Cereals	6 cwt. per acre 10:10:18
	Block II and III - Sugar Beet	
	Block IV - Grass	
1960	Block I - Grass	6 cwt. per acre 10:10:18
	Block II, III and IV - Sugar Beet	
1961	Potatoes	8 cwt. per acre 10:10:18

Table 78. Soil analysis, 1959, 1960 and 1961

Year	Experiment	pH	Available P	Available K
1959	Main experiment	6.2	mod. low	mod.
1960	Main experiment	6.3	mod. low	high
	Emergence trial	6.3	mod. low	mod. low
1961	Main experiment	6.2	mod. low	mod.
	Growth studies	-	-	-

Table 79 /

Table 79. Principal dates, 1959, 1960 and 1961

Year	Date of Sowing	Date of Singling	Date of Harvesting
1959	5th and 6th May	2nd June	18th-20th November
1960	5th and 6th May	30th May	Mid-November
1961	4th May	2nd-3rd June	8th December

Section IVD

(The effect of soluble førtiliser salts)

Table 80. Preceeding crop, and previous manuring, 1959, 1960 and 1961

Year	Preceeding crop	Previous manuring
1959	Cereals	3 cwt. per acre 14:6:20
1960	Cabbages	None
1961	Sugar Beet	12 cwt. per acre 10:10:18

Section IVE

(The effect of weeds)

Table 81. Preceeding crop, and manuring in trial year, 1959, 1960 and 1961

Year	Preceeding crop	Manuring
1959	Oats	7 cwt. per acre 12:12:18 15 tons per acre dung.
1960	Wheat	6 cwt. per acre 14:6:20. 15 tons per acre dung. 2 tons ground limestone
1961	Wheat	6 cwt. per acre 10:10:18. 15 tons per acre dung.

Table 82. Soil analysis, 1959, 1960 and 1961

Year	pH	Available P	Available K
1959	5.4	high	very high
1960	6.1	high	mod.
1961	6.1	mod. low	mod.

Section IVF

(The effect of exposing the hypocotyl
and the effect of the method of sowing)

Table 83. Preceeding crop, and manuring in trial year, 1960 and 1961

Year	Preceeding crop	Manuring
1960	wheat	6 cwt. per acre 14:6:20 15 tons per acre dung. 2 tons ground limestone
1961	wheat	6 cwt. per acre 10:10:18 15 tons per acre dung.

Table 84. Soil analysis, 1960 and 1961

Year	pH	Available P	Available K
1960	6.1	high	mod.
1961	6.1	mod. low	mod.

Section IVG

(The effect of plant population and distribution)

Table 85. Preceeding crop, and manuring in trial year 1960 and 1961

Year	Preceeding crop	Manuring
1960	Oats	6 cwt. 10:10:18
1961	Oats	6 cwt. 10:26:10

Table 86. Soil analysis, 1960 and 1961

Year	pH	Available P	Available K
1960	6.4	high	mod.
1961	-	-	-

APPENDIX B.

Statistical Analysis - Section IVC

(The effect of seed size)

Main Experiments

Table 87. Yield of sound roots, 1959. Analysis of variance.

Source	d.f.	SS	MS	VR
Total	47	61277.96		
Replicates	3	41119.69		
Spacing	3	460.60	153.53	0.40
Seed Size	2	2554.05	1277.02	3.32*
Spacing x Seed Size	6	4444.73	740.79	1.93
Error	33	12698.89	384.81	

Table 88. Yield of sound roots, 1959. Spacing x seed-size (tons per acre).

	5 inches	8 inches	11 inches	14 inches	
Large seed	25.6	26.1	29.0	26.1	
Graded seed	23.6	25.9	25.5	26.4	S.E. = ± 1.12
Small seed	25.8	25.1	23.0	25.0	

Table 89 /

Table 89. Yield of sound roots, 1960. Analysis of variance.

Source	d.f.	SS	MS	VR
Total	47	46208		
Replicates	3	8383		
Variety	3	12654	4218	7.17***
Seed Size	2	2222	1111	1.89
Spacing x Seed Size	6	3546	591	1.01
Error	33	19403	588	

Table 90. Yield of sound roots, 1960. Variety x seed-size (tons per acre).

	Best of All	Victory	Peerless	Superlative	
Large seed	31.8	33.8	32.7	31.7	
Graded seed	29.2	34.6	31.1	30.8	S.E. = ± 1.37
Small seed	27.3	34.3	32.6	28.1	

Table 91. Yield of sound roots, 1961. Analysis of variance.

Source	d.f.	SS	MS	VR
Total	47	80065.50		
Block	3	2681.10		
Spacing	3	2020.90	673.63	0.34
Seed Size	2	1635.10	817.55	0.42
Spacing x Seed Size	6	8989.40	1664.90	0.85
Error	33	64739.00	1961.80	

Table 92. Yield of sound roots, 1961. Spacing x Seed-Size (tons per acre).

	5 inches	8 inches	11 inches	14 inches	
Large seed	38.8	38.7	35.3	38.5	
Graded seed	35.8	36.6	40.1	35.9	S.E. = ± 2.51
Small seed	36.8	38.9	33.4	33.4	

Table 93. Yield of sound roots, 1959-61. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	143	426994		
Replicates/years	9	52184		
Years	2	239444	119722	122.41***
Seed Size	2	6265	3133	87.04***
Seed Size x years	4	145	36	0.04
Spacing + Var./years	9	15135	1682	1.19
Seed Size x spacing (Var.) / years	18	16980	943	0.96
Error	99	96841	978	

Testing the main effect of seed size against error with 99 d.f.

VR = 3.20*

Table 94 /

Table 94. Covariance Analysis: The number of sound roots harvested and the yield of sound roots, 1959.

Source	d.f.	Sum of Products			Errors of Estimate		
		x^2	xy	y^2	SS	DF	MS
Total	47	85475.31	- 8934.5	61277.96			
Replicates	3	1017.56	- 4342.6	41119.69			
Spacing	3	81001.73	- 5605.0	460.60			
Seed Size	2	483.50	- 1016.4	2554.05			
Spacing x Seed size	6	608.33	- 846.6	4444.73			
Error	33	2364.19	+ 843.3	12698.89	12398.09	32	387.44
Error + Seed Size	35	2847.69	1859.7	15252.94	14038.46	34	
Difference for testing adjusted means					1640.37	2	820.18

$$VR = \frac{820.18}{387.44} = 2.12; \quad F.05 = 3.30$$

Table 95. Yield of dry matter in the roots, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	534.05		
Replicates	3	266.46		
Spacing	3	22.96	7.65	1.84
Seed Size	2	66.29	33.14	7.98**
Spacing x Seed Size	6	41.31	6.88	1.66
Error	33	137.03	4.15	

Table 96 /

Table 96. Yield of dry matter in the roots, 1959. Spacing x seed-size (Cwt. per acre).

	5 inches	8 inches	11 inches	14 inches	
Large seed	63.8	65.2	68.8	61.0	
Graded seed	60.0	63.2	61.3	58.5	S.E. = ± 2.29
Small seed	62.5	60.3	53.8	56.5	

Table 97. Yield of dry matter in the roots, 1960. Analysis of variance.

Source	d.f.	SS	MS	VR
Total	47	534.83		
Replicates	3	49.87		
Variety	3	96.26	32.09	3.61*
Seed Size (linear)	1	40.27	40.27	4.52*
Seed Size (residual)	1	0.02	0.02	
Variety x Seed Size	6	55.15	9.19	1.03
Error	33	293.26	8.89	

Table 98 /

Table 98. Yield of dry matter in the roots, 1960. Variety x Seed-Size (cwt. per acre).

	Best of All	Victory	Peerless	Superlative	
Large seed	72.6	68.9	63.7	62.6	
Graded seed	63.0	73.1	59.5	61.6	S.E. = ± 4.58
Small seed	59.9	65.9	61.4	59.8	

Table 99. Yield of dry matter in the roots, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	652.90		
Replicates	3	3.10		
Spacing	3	124.75	41.58	3.17*
Seed size	2	27.03	13.51	1.03
Spacing x Seed Size	6	65.72	10.95	0.85
Error	33	432.30	13.10	

Table 100. Yield of dry matter in the roots, 1961. Spacing x Seed-Size (cwt. per acre).

	5 inches	8 inches	11 inches	14 inches	
Large seed	83.2	84.1	79.5	79.2	
Graded seed	78.5	78.5	84.5	72.6	S.E. = ± 4.12
Small seed	80.0	78.5	84.2	67.0	

Table 101 /

Table 101. Yield of dry matter in the roots 1959-61. Analysis of variance.

Source	d.f.	SS	MS	VR
Total	143	3459.18		
Replicates/years	9	319.43		
Years	2	1677.41	838.70	62.64**
Seed Size	2	125.62	62.81	50.65**
Seed Size x years	4	4.97	1.24	
Spacing and Var./years	9	243.97		
Seed Size x Spacing (var.)/Years	18	162.18		
Error	99	1325.60	13.39	

Testing the main effect of seed size against error with 99 d.f.,

$VR = 4.69^{*}$ ($F.01 = 4.82$)

Table 102. Dry matter percentage of the roots, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	36.6091		
Replicates	3	19.3781		
Spacing	3	7.9426	2.6475	12.18**
Seed Size	2	1.0485	0.5242	2.41
Spacing x Seed Size	6	1.0679	0.1779	0.82
Error	33	7.1720	0.2173	

Table 103 /

Table 103. Dry matter percentage of the roots, 1959. Spacing x Seed-Size.

	5 inches	8 inches	11 inches	14 inches	
Large seed	12.54	12.51	11.95	11.77	
Graded seed	12.72	12.27	12.11	11.13	S.E. = ± 0.23
Small seed	12.18	12.13	11.68	11.35	

Table 104. Dry matter percentage of the roots, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	35.4066		
Replicates	3	6.0433		
Variety	3	13.0969	4.3657	11.99***
Seed Size	2	0.1970	0.0985	0.27
Variety x Seed Size	6	4.0564	0.6760	1.86
Error	33	12.0130	0.3640	

Table 105. Dry matter percentage of the roots, 1960. Variety x Seed-Size.

	Best of All	Victory	Peerless	Superlative	
Large seed	11.38	10.23	9.73	9.89	
Graded seed	10.75	10.55	9.58	10.05	S.E. = ± 0.30
Small seed	10.96	9.59	9.39	10.65	

Table 106 /

Table 106. Dry matter percentage of the roots, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	24.0071		
Replicates	3	1.6584		
Spacing	3	3.5322	1.1774	2.19
Seed Size	2	0.0771	0.0385	0.01
Spacing x Seed Size	6	1.0276	0.1713	.03
Error	33	17.7118	0.5367	

Table 107. Dry matter percentage in the roots, 1961. Spacing x seed-size

	5 inches	8 inches	11 inches	14 inches	
Large seed	10.79	10.99	11.01	10.28	
Graded seed	10.97	10.73	10.53	10.45	S.E. = $\pm$0.37
Small seed	10.98	11.01	10.85	10.03	

Table 108. Yield of tops, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	6513.62		
Replicates	3	4480.18		
Spacing	3	755.72	251.90	7.18**
Seed Size	2	17.57	8.79	0.25
Spacing x Seed Size	6	102.14	17.02	0.49
Error	33	1158.01	35.09	

Table 109. Yield of tops, 1959. Spacing x seed size (tons per acre).

	5 inches	8 inches	11 inches	14 inches	
Large seed	4.36	3.35	3.49	3.39	
Graded seed	4.35	3.63	3.35	3.52	S.E. = ±0.33
Small seed	4.73	3.97	3.07	4.69	

Table 110. Yield of tops, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	2535		
Replicates	3	187		
Variety	3	883	294	7.74**
Seed Size	2	14	7	0.18
Variety x seed size	6	190	31	0.81
Error	33	1261	38	

Table 111. Yield of tops, 1960. Variety x seed-size (tons per acre).

	Best of All	Victory	Peerless	Superlative	
Large seed	3.37	3.86	3.06	2.92	
Graded seed	3.97	3.49	2.66	2.83	S.E. = ±0.35
Small seed	4.20	3.86	2.46	3.03	

Table 112. /

Table 112. Yield of tops, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	4790.48		
Replicates	3	468.40		
Spacing	3	515.06	171.69	2.01
Seed Size	2	49.57	24.78	0.29
Spacing x Seed Size	6	936.72	156.12	1.82
Error	33	2820.73	85.48	

Table 113. Yield of tops, 1961. Spacing x seed-size (tons per acre).

	5 inches	8 inches	11 inches	14 inches	
Large seed	4.75	5.09	3.00	3.49	
Graded seed	4.86	3.36	4.42	4.05	S.E. = ± 0.52
Small seed	4.32	3.73	4.16	3.36	

Table 114. Post-singling plant count, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	138586		
Replicates	3	2		
Spacing	3	137125	45708	1632.42***
Seed Size	2	132	66	2.32
Spacing x Seed Size	6	389	65	2.32
Error	33	938	28	

Table 115. /

Table 115. Post-singling plant count, 1959. Spacing x Seed-Size (plants per acre).

	5 inches	8 inches	11 inches	14 inches	
Large seed	58,432	38,336	29,312	23,936	
Graded seed	61,440	38,208	28,480	23,296	S.E. = ±691
Small seed	57,856	38,208	28,096	23,168	

Table 116. Post-singling plant count, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	2239		
Replicates	3	708		
Variety	3	249	83	3.95*
Seed Size	2	91	45	2.14
Spacing x Seed Size	6	492	82	3.90*
Error	33	699	21	

Table 117. Post-singling plant count, 1960. Variety x Seed-Size (plants per acre).

	Best of All	Victory	Peerless	Superlative	
Large seed	31,744	33,920	32,064	32,832	
Graded seed	31,744	30,656	32,832	32,192	S.E. = ±589
Small seed	31,104	33,408	31,488	34,240	

Table 118. /

Table 118. Post-singling plant count, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	140873		
Replicates	3	54		
Spacing	3	138946	46315	1052.62**
Seed Size	2	18	9	0.20
Spacing x Seed Size	6	392	65	1.48
Error	33	1463	44	

Table 119. Post-singling plant count, 1961. Spacing x seed-size (plants per acre).

	5 inches	8 inches	11 inches	14 inches	
Large seed	60,096	37,120	28,096	22,720	
Graded seed	57,024	38,592	28,352	22,720	S.E. = ± 845
Small seed	59,520	37,312	28,544	22,656	

Table 120. Number of sound roots harvested, 1959. Analysis of Variance

Source	d.f.	SS	MS	VR
Total	47	85475		
Replicates	3	1018		
Spacing	3	81002	27001	375.19**
Seed Size	2	483	241	3.35*
Spacing x Seed Size	6	608	101	1.40
Error	33	2634	72	

Table 121. Number of sound roots harvested, 1959. Spacing x seed-size (roots per acre)

	5 inches	8 inches	11 inches	14 inches	
Large seed	52,160	36,544	28,288	22,848	
Graded seed	51,392	36,032	27,584	22,272	S.E. = ± 1075
Small seed	46,848	36,288	27,072	21,824	

Table 122. Number of sound roots harvested, 1960. Analysis of Variance

Source	d.f.	SS	MS	VR
Total	47	3524		
Replicates	3	1013		
Variety	3	1164	388	11.75***
Seed Size	2	59	29	0.88
Variety x Seed Size	6	209	35	1.06
Error	33	1079	33	

Table 123. Number of sound roots harvested, 1960. Variety x Seed-Size (roots per acre)

	Best of All	Victory	Peerless	Superlative	
Large seed	28,288	30,592	28,416	31,360	
Graded seed	28,544	28,800	28,352	30,208	S.E. = ±742
Small seed	28,224	30,016	26,944	31,744	

Table 124 /

Table 124. Number of sound roots harvested, 1961. Analysis of Variance

Source	d.f.	SS	MS	VR
Total	47	101169		
Replicates	3	211		
Spacing	3	100007	33336	1389.00***
Seed Size	2	36	18	0.75
Spacing x Seed Size	6	127	21	0.87
Error	33	788	24	

Table 125. Number of sound roots harvested, 1961. Spacing x seed-size (roots per acre)

	5 inches	8 inches	11 inches	14 inches	
Large seed	53,504	35,008	27,712	22,400	
Graded seed	53,056	36,800	27,328	22,336	S.E. = ± 640
Small seed	53,376	36,416	28,544	22,464	

Table 126. Length of first foliage leaf 2 weeks after singling, 1959 (Analysis of Variance)

Source	d.f.	SS	MS	VR
Total	47	136.14		
Replicates	3	70.39		
Spacing	3	6.19	2.06	3.81*
Seed Size	2	37.83	18.91	35.02***
Spacing x Seed Size	6	3.94	0.65	1.20
Error	33	17.79	0.54	

Table 127. Mean length of first foliage leaf 2 weeks after singling, 1959
Spacing x seed-size (cm.)

	5 inches	8 inches	11 inches	14 inches	
Large seed	15.0	14.4	14.1	14.4	
Graded seed	14.7	14.0	14.6	14.5	S.E. = $\pm$ .37
Small seed	13.6	12.6	12.7	11.9	

Table 128. Length of first foliage leaf 4 weeks after singling, 1959
Analysis of Variance

Source	d.f.	SS	MS	VR
Total	47	656.44		
Replicates	3	342.61		
Spacing	3	74.74	28.25	6.66***
Seed Size	2	78.33	39.17	9.24***
Spacing x Seed Size	6	20.68	3.45	0.81
Error	33	140.08	4.24	

Table 129. Mean length of first foliage leaf 4 weeks after singling, 1959
Spacing x seed-size (cm.)

	5 inches	8 inches	11 inches	14 inches	
Large seed	45.4	41.0	41.0	40.9	
Graded seed	42.0	40.8	38.6	39.9	S.E. = $\pm$ 3.25
Small seed	40.3	38.2	38.9	38.6	

Table 130. Length of first foliage leaf 2 weeks after singling, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	96.40		
Replicates	3	36.84		
Variety	3	3.96	1.32	2.16
Seed Size	2	30.98	15.49	25.39***
Spacing x Seed Size	6	4.34	0.72	1.18
Error	33	20.28	0.61	

Table 131. Mean length of first foliage leaf 2 weeks after singling, 1960. Variety x seed-size (cm.)

	5 inches	8 inches	11 inches	14 inches	
Large	12.6	13.0	12.9	12.1	
Graded seed	13.6	12.1	12.5	12.2	S.E. = $\pm$0.39
Small seed	11.2	10.9	10.9	10.7	

Table 132 /

Table 132. Length of first foliage leaf 4 weeks after singling, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	687.33		
Replicates	3	245.07		
Variety	3	36.20	12.07	1.09
Seed Size	2	9.47	4.73	0.43
Spacing x Seed Size	6	31.31	5.22	0.47
Error	33	365.28	11.07	

Table 133. Mean length of first foliage leaf 4 weeks after singling, 1960. Variety x seed-size (cm.)

	Best of All	Victory	Peerless	Superlative	
Large seed	43.5	41.9	44.9	41.9	
Graded seed	43.3	42.7	43.5	40.8	S.E. = ±1.65
Small seed	42.6	45.6	44.1	42.5	

Table 134 /

Table 134. Length of first foliage leaf 2 weeks after singling, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	57.00		
Replicates	3	17.57		
Spacing	3	1.63	0.54	0.91
Seed Size	2	17.66	8.83	14.96***
Spacing x Seed Size	6	0.80	0.13	0.22
Error	33	19.34	0.59	

Table 135. Mean length of first foliage leaf 2 weeks after singling, 1961. Spacing x Seed-Size (Cm.)

	5 inches	8 inches	11 inches	14 inches	
Large seed	13.4	13.6	13.9	13.9	
Graded seed	12.9	12.8	13.6	13.3	S.E. = ± 0.38
Small seed	11.9	12.3	12.3	12.2	

Table 136 /

Table 136. Length of first foliage leaf 4 weeks after singling, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	240.46		
Replicates	3	58.98		
Spacing	3	1.65	0.55	1.11
Seed Size	2	6.59	3.29	0.66
Spacing x Seed Size	6	9.72	1.62	0.33
Error	33	163.52	4.95	

Table 137. Mean length of first foliage leaf 4 weeks after singling, 1961. Spacing x seed-size (cm.)

	5 inches	8 inches	11 inches	14 inches	
Large seed	28.4	29.3	27.3	28.5	
Graded seed	29.1	27.9	28.9	28.7	S.E. = $\pm$1.11
Small seed	27.9	27.8	27.7	27.7	

Table 138. Number of plants to emerge per plot, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	1501,515		
Replicates	3	340,924		
Seed Size	2	623,775	311,887	24.40***
Error	42	536,812	12,781	

Table 139 /

Table 139. Rate Index, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	0.1164		
Replicates	3	0.0666		
Seed Size	2	0.0022	0.0011	1.00
Error	42	0.0476	0.0011	

Table 140. Number of plants to emerge per plot, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	272,047		
Replicates	3	37,712		
Variety	3	80,864	26,955	11.90^{***}
Seed Size	2	22,627	11,314	4.99^{*}
Variety x Seed Size	6	56,144	9,357	4.13^{***}
Error	33	74,700	2,264	

Table 141. Number of plants to emerge per 12 feet of plot row, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	115,561		
Replicates	3	10,950		
Seed Size	2	1,283	641	0.26
Error	42	103,328	2,460	

Sub-experiments

Table 142. Germination percentage, 1959-1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	26	263		
Blocks	8	239		
Seed Size	2	5	2.5	2.10
Error	16	19	1.2	

Table 143. Germination Rate Index, 1959 and 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	14	6216.42		
Blocks	4	5697.47		
Seed Size	2	62.07	31.03	0.54
Error	8	456.88	57.11	

Table 144. Emergence Test, 1960. Number of plants to emerge per plot at first count. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	59	3098		
Replicates	4	179		
Variety	3	1878	626	29.81***
Seed-Size	2	19	9	0.43
Variety x Seed Size	6	104	17	0.81
Error	44	918	21	

Table 145. Emergence Test, 1960. Emergence percentage at first count. Variety x Seed-Size.

	Best of All	Victory	Peerless	Superlative	
Large seed	39.2	17.6	32.4	12.0	
Graded seed	43.2	11.2	34.0	19.2	S.E. = ±4.0
Small seed	41.6	16.0	25.6	13.6	

Table 146. Emergence Test, 1960. Number of plants to emerge per plot at final count. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	59	828		
Replicates	4	46		
Variety	3	163	54	4.50**
Seed Size	2	32	16	1.33
Variety x Seed Size	6	76	13	1.08
Error	33	511	12	

Table 147. Emergence Test, 1960. Emergence percentage at final count, Variety x Seed-Size.

	Best of All	Victory	Peerless	Superlative	
Large seed	82.4	74.8	82.8	72.4	
Graded seed	82.4	76.0	83.6	81.2	S.E. = ±3.2
Small seed	82.8	78.0	78.0	78.0	

Table 148. /

Table 148. Emergence Rate Index, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	59	0.4072		
Replicates	4	0.0129	0.0032	
Variety	3	0.2358	0.0786	25.35***
Seed Size	2	0.0036	0.0018	0.58
Variety x Seed Size	6	0.0178	0.0029	0.93
Error	44	0.1371	0.0031	

Table 149. Emergence Rate Index, 1960. Variety x Seed-Size.

	Best of All	Victory	Peerless	Superlative	
Large seed	.825	.690	.808	.702	
Graded seed	.847	.672	.808	.734	S.E. = ± .025
Small seed	.854	.698	.751	.683	

Table 150. Experiment d (1961). Emergence percentage at first count. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	53	4116	78	
Replicates	5	527	105	
Seed Size	2	41	21	0.27
Error	46	3548	77	

Table 151 /

Table 151. Experiment d (1961). Emergence percentage at final count. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	53	3615		
Replicates	5	392		
Seed Size	2	72	36	0.53
Error	46	3151	68	

Table 152. Experiment d (1961). Emergence Rate Index. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	53	.0609		
Replicates	5	.0085		
Seed Size	2	.0004	.0002	.01
Error	46	.0520	.0013	

Table 153. Experiment d (1961). Area of cotyledons. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	53	.0930		
Replicates	5	.0060		
Seed Size	2	.0676	.0338	84.50***
Error	46	.0194	.0004	

Table 154 /

Table 154. Experiment d (1961). Length of first foliage leaf before singling. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	53	6.6157		
Replicates	5	1.2128		
Seed Size	2	1.3842	0.6921	7.92***
Error	46	4.0187	0.0874	

Table 155. Mean length of first foliage leaf before singling (inches)

Large seed - 1.98	
Graded seed - 1.87	S.E. = ± 0.07
Small seed - 1.60	

Table 156. Experiment d (1961). Area of first foliage leaf before singling. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	53	7.0166		
Replicates	5	0.9023	0.1805	
Seed Size	2	1.6792	0.8396	8.71***
Error	46	4.4351	0.0964	

Table 157 /

Table 157. Mean area of first foliage leaf before singling (sq. inches)

Large seed	- 1.27	
Graded seed	- 1.08	S.E. = ±0.07
Small seed	- 0.84	

Table 158. Experiment d (1961). Total leaf area before singling.
Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	53	40.8482		
Replicates	5	5.9147		
Seed Size	2	10.8914	5.4457	10.42^{***}
Error	46	24.0421	0.5226	

Table 159. Mean leaf area per plant before singling (sq. inches)

Large seed	- 3.02	
Graded seed	- 2.56	S.E. = ± 0.17
Small seed	- 1.92	

Table 160 /

Table 160. Experiment d (1961). Length of first foliage leaf at 2 stages of growth - post singling. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	35			
Replicates	5	1.2270	0.2454	
Stage of growth	1	9.1084	9.1084	33.21**
Seed Size	2	2.7284	1.3642	4.97*
Stage x seed size	2	1.0179	0.5089	1.85
Error	25		0.2742	

Table 161. Mean length of first foliage leaf after singling. Stage of growth x seed size (inches).

	1	2	
Large seed -	3.42	4.83	
Graded seed -	3.40	4.34	S.E. = ± .21
Small seed -	3.09	3.82	

Table 162. Experiment d (1961). Area of first foliage leaf at 2 stages of growth - post singling. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	35	99.4903		
Replicates	5	6.2804	1.2561	
Stage of Growth	1	36.6015	36.6015	23.59**
Seed Size	2	16.1804	8.0922	5.22*
Stage x Seed Size	2	1.6499	0.8249	0.53
Error	25	38.7781	1.5511	

Table 163. Mean area of first foliage leaf after singling. Stage of growth x seed size (sq. inches).

	1	2	
Large seed	4.01	6.59	
Graded seed	3.82	5.65	S.E. = ± .51
Small seed	2.85	4.49	

Table 164. Experiment d (1961). Total leaf area at 2 stages of growth - post singling. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	35	1184.5103		
Replicates	5	50.6205		
Stage of growth	1	580.0876	580.0876	39.94***
Seed Size	2	157.8567	78.9284	5.43*
Stage x Seed Size	2	32.8921	16.4460	1.13
Error	25	363.0534	14.5221	

Table 165. Mean leaf area per plant after singling. Stage of growth x seed size (sq. inches)

	1	2	
Large seed	11.06	21.78	
Graded seed	10.17	17.32	S.E. = ± 1.55
Small seed	8.10	14.49	

Table 166. Experiment d (1961). Fresh weight of isolated roots. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	49	54,854.436		
Block	5	6,110.171		
Seed Size	2	783.688	391.844	0.34
Error	42	47,960.577	1,141.918	

Table 167. Mean fresh weight of isolated roots (lb.)

Large seed	- 7.3	
Graded seed	- 7.0	S.E. = ± .57
Small seed	- 7.7	

Table 168. Experiment d (1961). Weight of dry matter of isolated roots. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	49	554,126.67		
Replicates	5	38,178.40		
Seed Size	2	20,153.27	10,076.63	0.85
Error	42	495,795.00	11,804.64	

Table 169 /

Table 169. Mean weight of dry matter of isolated roots (lb.)

Large seed - .78		
Graded seed - .73		S.E. = ± .06
Small seed - .83		

Table 170. Experiment d (1961). Fresh weight of tops of isolated roots. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	49	1,257,092		
Replicates	5	133,900		
Seed Size	2	38,339	19,170	0.74
Error	42	1,084,853	25,830	

Table 171. Mean fresh weight of tops from isolated roots (lb.)

Large seed - .91		
Graded seed - .87		S.E. = ± .09
Small seed - 1.01		

Table 172 /

Table 172. Experiment d (1961). Dry weight of tops of isolated roots Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	49	17,771.74		
Replicates	5	3,198.25		
Seed Size	2	49.20	24.60	0.07
Error	42	14,524.29	345.82	

Table 173. Mean dry weight of tops of isolated roots (lb.)

Large seed - .12		
Graded seed - .11		S.E. = ± .01
Small seed - .12		

APPENDIX B.

Statistical Analysis - Section IVD

(The effect of soluble fertiliser salts)

Table 174. Number of plants emerged at the first count, 1959.

Analysis of Variance

Source	d.f.	SS	MS	VR
Total	26	16298		
Blocks	2	3335		
N (linear)	1	2156	2156	4.79*
N (residual)	1	16	16	0.03
P	2	420	210	0.47
K	2	462	231	0.51
N x P (linear x linear)	1	690	690	1.53
N x K (linear x linear)	1	690	690	1.53
P x K (linear x linear)	1	1784	1784	3.97
Error	15	6745	450	

Table 175 /

Table 175. Percentage emergence at the first count, 1959.

1. Levels of nitrogen

n_o = 12.2		
n_1 = 10.7	SE = ± 1.02	
n_2 = 8.9		

4. Nitrogen x phosphorus

	n_o	n_1	n_2	
p_o	10.3	9.5	9.5	
p_1	12.2	12.7	8.5	S.E. = ± 1.87
p_2	13.8	10.0	8.6	

2. Levels of phosphorus

p_o = 9.2		
p_1 = 11.1	SE = ± 1.02	
p_2 = 10.9		

5. Nitrogen x potassium

	n_o	n_1	n_2	
k_o	13.2	12.1	8.7	
k_1	13.8	9.1	8.8	SE = ± 1.87
k_2	9.3	10.9	9.1	

3. Levels of potassium

k_o = 11.3		
k_1 = 10.6	SE = ± 1.02	
k_2 = 9.8		

6. Phosphorus x potassium

	p_o	p_1	p_2	
k_o	8.7	12.0	13.3	
k_1	9.5	12.0	10.6	SE = ± 1.87
k_2	11.4	9.5	8.6	

Table 176 /

Table 176. Number of plants emerged at the final count, 1959.

Analysis of Variance

Source	d.f.	SS	MS	VR
Total	26	27076		
Blocks	2	308		
N	2	744	372	0.23
P	2	3221	1610	0.98
K	2	3595	1797	1.09
N x P (linear x linear)	1	1141	1141	0.69
N x K (linear x linear)	1	192	192	0.12
P x K (linear x linear)	1	3234	3234	1.97
Error	15	24641	1643	

Table 177. /

Table 177. Percentage emergence at the final count, 1959.

1. Levels of nitrogen

n_o = 45.9		
n_1 = 43.9	SE = ± 2.11	
n_2 = 45.1		

2. Levels of phosphorus

p_o = 46.5		
p_1 = 45.7	SE = ± 2.11	
p_2 = 42.7		

3. Levels of potassium

k_o = 46.5		
k_1 = 45.8	SE = ± 2.11	
k_2 = 42.6		

4. Nitrogen x phosphorus

	n_o	n_1	n_2	
p_o	49.0	44.6	45.8	
p_1	45.1	48.4	43.7	SE = ± 3.36
p_2	43.5	38.9	45.9	

5. Nitrogen x potassium

	n_o	n_1	n_2	
k_o	45.2	47.0	47.4	
k_1	49.9	41.8	45.6	SE = ± 3.36
k_2	42.4	43.2	42.3	

6. Phosphorus x potassium

	p_o	p_1	p_2	
k_o	43.7	49.7	46.2	
k_1	48.4	47.0	41.9	SE = ± 3.36
k_2	47.3	40.3	40.3	

Table 178. /

Table 178. Number of plants emerged at the first count, 1960

Analysis of Variance

Source	d.f.	SS	MS	VR
Total	26	58867		
Block	2	1308		
N (linear)	1	8404	8404	4.21
N (residual)	1	218	218	0.11
P	2	7191	3595	1.80
k_o v k_1 k_2	1	7585	7585	3.80
k_1 v k_2	1	9	9	0.004
N x P (linear x linear)	1	1	1	0.0005
N x K (linear x linear)	1	4144	444	0.22
P x K (linear x linear	1	52	52	0.03
Error	15	29955	1997	

Table 179. /

Table 179. Percentage emergence at the first count, 1960.

1. Levels of nitrogen

n_o = 38.7

n_1 = 34.9 SE = ± 3.00

n_2 = 30.0

2. Levels of phosphorus

p_o = 32.3

p_1 = 39.1 SE = ± 3.00

p_2 = 32.1

3. Levels of potassium

k_o = 30.0

k_1 = 37.0 SE = ± 3.00

k_2 = 36.8

4. Nitrogen x phosphorus

	n_o	n_1	n_2	
p_o	34.3	37.0	25.5	
p_1	41.4	43.5	32.5	SE = ± 5.20
p_2	40.4	24.1	31.9	

5. Nitrogen x potassium

	n_o	n_1	n_2	
k_o	35.9	33.4	20.1	
k_1	43.2	33.9	34.0	SE = ± 5.20
k_2	37.0	37.3	35.9	

6. Phosphorus x potassium

	p_o	p_1	p_2	
k_o	25.3	34.5	29.6	
k_1	40.9	40.0	30.1	SE = ± 5.20
k_2	30.7	42.9	36.7	

Table 180. /

Table 180. Number of plants emerged at the final count, 1960.

Analysis of Variance

Variance	d.f.	SS	MS	VR
Total	26	27968		
Blocks	2	2881		
N (linear)	1	4449	4449	4.91*
N (residual)	1	690	690	0.76
P	2	2218	1109	1.22
K	2	1245	622	0.69
N x P (linear x linear)	1	261	261	0.29
N x K (linear x linear)	1	2437	2437	2.69
P x K (linear x linear)	1	184	184	0.20
Error	15	13603	907	

Table 181. /

Table 181. Percentage emergence at the final count, 1960

1. Levels of nitrogen

$n_o = 75.4$

$n_1 = 74.4$ SE = $\pm$ 2.00

$n_2 = 69.1$

2. Levels of phosphorus

$p_o = 71.3$

$p_1 = 75.7$ SE = $\pm$ 2.00

$p_2 = 73.8$

3. Levels of potassium

$k_o = 73.8$

$k_1 = 75.3$ SE = $\pm$ 2.00

$k_2 = 71.9$

4. Nitrogen x phosphorus

	n_o	n_1	n_2	
p_o	73.7	76.3	63.9	
p_1	76.0	78.1	73.0	SE = $\pm$ 3.6
p_2	78.5	70.7	72.4	

5. Nitrogen x potassium

	n_o	n_1	n_2	
k_o	78.9	77.0	65.5	
k_1	76.2	76.5	72.9	SE = $\pm$ 3.6
k_2	73.0	67.0	70.9	

6. Phosphorus x potassium

	p_o	p_1	p_2	
k_o	70.3	75.2	75.9	
k_1	75.1	75.8	74.6	SE = $\pm$ 3.6
k_2	68.5	76.1	71.0	

Table 182. /

Table 182. Number of plants emerged at the first count, 1961.
Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	26	9527		
Block	2	27		
N	2	2369	1185	4.40*
P	2	374	187	0.69
k_0 v k_1 k_2	1	1932	1932	7.18*
k_1 v k_2	1	25	25	0.09
N x P (linear x linear)	1	56	56	0.21
N x K (linear x linear)	1	24	24	0.09
P x K (linear x linear)	1	690	690	2.56
Error	15	4030	269	

Table 183. /

Table 183. Percentage emergence at the first count, 1961.

1. Levels of nitrogen

$n_o = 50.2$

$n_1 = 44.3$ SE = $\pm$ 1.53

$n_2 = 45.1$

2. Levels of phosphorus

$p_o = 47.0$

$p_1 = 47.5$ SE = $\pm$ 1.53

$p_2 = 45.0$

3. Levels of potassium

$k_o = 43.3$

$k_1 = 48.6$ SE = $\pm$ 1.53

$k_2 = 47.8$

4. Nitrogen and phosphorus

	n_o	n_1	n_2	
p_o	50.2	47.2	43.7	
p_1	48.7	44.9	48.8	SE = $\pm$ 2.64
p_2	51.7	40.8	42.8	

5. Nitrogen x potassium

	n_o	n_1	n_2	
k_o	45.7	42.3	41.6	
k_1	54.6	44.8	46.1	SE = $\pm$ 2.64
k_2	50.2	45.8	47.6	

6. Phosphorus x potassium

	p_o	p_1	p_2	
k_o	44.8	45.3	39.5	
k_1	50.5	48.1	46.8	SE = $\pm$ 2.64
k_2	45.7	49.0	48.9	

Table 184. /

Table 184. Number of plants emerged at the final count, 1961.

Source	d.f.	SS	MS	VR
Total	26	5635		
Block	2	47		
N (linear)	1	1200	1200	5.69**
N (residual)	1	16	16	0.08
P	2	86	43	0.20
K	2	648	324	1.53
N x P (linear x linear)	1	52	52	0.24
N x K (linear x linear)	1	33	33	0.16
P x K (linear x linear)	1	385	385	1.82
Error	15	3168	211	

Table 185. /

Table 185. Percentage emergence at the final count, 1961.

1. Levels of nitrogen

$n_o = 84.1$

$n_1 = 81.4$ SE = $\pm$ 1.34

$n_2 = 79.5$

2. Levels of phosphorus

$p_o = 81.4$

$p_1 = 82.3$ SE = $\pm$ 1.34

$p_2 = 81.2$

3. Levels of potassium

$k_o = 83.3$

$k_1 = 80.1$ SE = $\pm$ 1.34

$k_2 = 81.6$

4. Nitrogen x phosphorus

	n_o	n_1	n_2	
p_o	85.4	81.2	77.7	
p_1	82.0	83.5	81.6	SE = $\pm$ 2.34
p_2	84.8	79.3	79.4	

5. Nitrogen x potassium

	n_o	n_1	n_2	
k_o	85.2	84.0	80.8	
k_1	83.6	79.5	76.8	SE = $\pm$ 2.34
k_2	83.4	80.5	80.9	

6. Phosphorus x potassium

	p_o	p_1	p_2	
k_o	84.0	84.7	81.3	
k_1	80.8	79.9	79.3	SE = $\pm$ 2.34
k_2	79.4	82.4	83.0	

Table 186. /

Table 186. Rate index, 1959 - 1961.

Analysis of Variance

Source	d.f.	SS	MS	VR
Total	80	0.503952		
Years	2	0.378094	0.189047	189.70^{***}
Blocks/years	6	0.021963		
N	2	0.018313	0.009157	34.68^{***}
P	2	0.007616	0.003808	3.99
K	2	0.008680	0.004340	2.78
N x P (linear x linear)	1	0.000441	0.000441	
N x K (linear x linear)	1	0.004970	0.004970	5.04^{*}
P x K (linear x linear)	1	0.002434	0.002434	2.47
N x years	4	0.001055	0.000264	
P x years	4	0.003821	0.000955	
K x years	4	0.006245	0.001561	
N x P x years	8	0.005489		
N x K x years	8	0.002300		
P x K x years	8) 51	0.010347	0.000986	
Error	27	0.032184		

Table 187. /

Table 187. Mean rate index 1959-1961.

1. Nitrogen x phosphorus

	n_o	n_1	n_2	
p_o	.793	.777	.761	
p_1	.813	.800	.786	SE = ± 0.0104
p_2	.816	.762	.771	

2. Phosphorus x potassium

	p_o	p_1	p_2	
k_o	.746	.789	.780	
k_1	.800	.803	.783	SE = ± 0.0104
k_2	.783	.806	.785	

Table 188. /

Table 188. The length of first foliage leaf 3 weeks after singling, 1959 (c.m.)

Analysis of variance

Source	d.f.	SS	MS	VR
Total	26	219.23		
Block	2	9.92		
N	2	37.92	18.96	4.69*
P	2	18.46	9.23	2.28
K	2	49.70	24.85	6.15*
N x P (linear x linear)	1	36.75	36.75	9.09**
N x K (linear x linear)	1	5.60	5.60	1.39
P x K (linear x linear)	1	0.30	0.30	
Error	15	60.58	4.04	

Table 189. /

Table 189. Mean length of first foliage leaf 3 weeks after singling, 1959 (c.m.)

1. Levels of nitrogen

n_o = 16.8

n_1 = 19.7 SE = ± 0.67

n_2 = 18.5

2. Levels of phosphorus

p_o = 17.2

p_1 = 19.2 SE = ± 0.67

p_2 = 18.6

3. Levels of potassium

k_o = 16.4

k_1 = 19.2 SE = ± 0.67

k_2 = 19.4

4. Nitrogen x potassium

	n_o	n_1	n_2	
k_o	15.3	18.6	15.4	
k_1	17.9	19.7	20.0	SE = ± 1.16
k_2	17.3	20.8	20.1	

5. Phosphorus x potassium

	p_o	p_1	p_2	
k_o	15.2	17.8	16.3	
k_1	17.8	19.3	20.4	SE = ± 1.16
k_2	18.6	20.5	19.1	

Table 190. /

Table 190. The length of first foliage leaf 3 weeks after singling, 1960 (c.m.). Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	26	140.24		
Block	2	2.58		
N	2	31.48	15.74	4.37*
P	2	28.48	14.24	3.95*
K	2	0.43	0.21	0.06
N x P (linear x linear)	1	20.80	20.80	5.78*
N x K (linear x linear)	1	2.52	2.52	0.70
P x K (linear x linear)	1	0.01	0.01	0.003
Error	15	53.94	3.60	

Table 191. /

Table 191. Mean length of first foliage leaf 3 weeks after singling, 1960 (c.m.)

1. Levels of nitrogen

n_o = 21.8		
n_1 = 24.1	SE = $\pm$ 0.63	
n_2 = 24.0		

2. Levels of phosphorus

p_o = 21.9		
p_1 = 24.1	SE = $\pm$ 0.63	
p_2 = 23.9		

3. Levels of potassium

k_o = 23.4		
k_1 = 23.1	SE = $\pm$ 0.63	
k_2 = 23.3		

4. Nitrogen x potassium

	n_o	n_1	n_2	
k_o	22.9	24.0	23.4	
k_1	20.6	24.2	24.3	SE = $\pm$ 1.10
k_2	21.9	23.8	24.3	

5. Phosphorus x potassium

	p_o	p_1	p_2	
k_o	22.1	24.8	23.5	
k_1	21.4	23.1	24.9	SE = $\pm$ 1.10
k_2	22.1	24.5	23.5	

Table 192. /

Table 192. The length of first foliage leaf 3 weeks after singling, 1961 (c.m.). Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	26	149.97		
Block	15	0.76		
N	2	49.01	24.51	9.84***
P	2	23.24	11.63	4.67*
K (linear)	1	12.83	12.83	5.15*
K (residual)	1	4.18	4.18	1.68
N x P (linear x linear)	1	20.02	20.02	8.04*
N x K (linear x linear)	1	2.52	2.52	1.01
P x K (linear x linear)	1	0.08	0.08	0.03
Error	15	37.33	2.49	

Table 193. /

Table 193. Mean length of first foliage leaf 3 weeks after singling, 1961 (c.m.)

1. Levels of nitrogen

n_o = 20.1

n_1 = 22.0 SE = $\pm$ 0.52

n_2 = 23.4

4. Nitrogen x potassium

	n_o	n_1	n_2	
k_o	19.2	21.5	21.4	
k_1	20.9	21.8	24.5	SE = $\pm$ 0.91
k_2	20.2	22.7	24.3	

2. Levels of phosphorus

p_o = 20.5

p_1 = 22.5 SE = $\pm$ 0.52

p_2 = 22.5

5. Phosphorus x potassium

	p_o	p_1	p_2	
k_o	19.1	22.3	20.8	
k_1	21.2	22.4	23.6	SE = $\pm$ 0.91
k_2	21.3	22.7	23.2	

3. Levels of potassium

k_o = 20.7

k_1 = 22.4 SE = $\pm$ 0.52

k_2 = 22.4

Table 194. /

Table 194. Number of leaves per plant 3 weeks after singling, 1960.
Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	26	19.05		
Block	2	2.69		
N	2	2.22	1.11	1.79
P	2	2.99	1.50	2.42
K	2	0.63	0.32	0.52
N x P (linear x linear)	1	0.33	0.33	0.53
N X K (linear x linear)	1	0.91	0.91	1.47
P x K (linear x linear)	1	0.05	0.05	0.08
Error	15	9.23	0.62	

Table 195. /

Table 195. Mean number of leaves per plant 3 weeks after singling, 1960.

1. Levels of nitrogen

n_o = 9.7

n_1 = 9.9 SE = ± 0.26

n_2 = 10.4

2. Levels of phosphorus

p_o = 9.5

p_1 = 10.3 SE = ± 0.26

p_2 = 10.2

3. Levels of potassium

k_o = 10.2

k_1 = 9.8 SE = ± 0.26

k_2 = 9.9

4. Nitrogen x phosphorus

	n_o	n_1	n_2	
p_o	7.3	7.7	7.8	
p_1	7.4	7.9	7.9	SE = ± 0.46
p_2	7.9	7.9	7.9	

5. Nitrogen x potassium

	n_o	n_1	n_2	
k_o	7.7	7.6	7.9	
k_1	7.3	8.1	8.0	SE = ± 0.46
k_2	7.5	7.7	7.8	

6. Phosphorus x potassium

	p_o	p_1	p_2	
k_o	7.6	7.6	7.9	
k_1	7.4	7.9	8.1	SE = ± 0.46
k_2	7.6	7.6	7.7	

Table 196. /

Table 196. Number of leaves per plant 3 weeks after singling, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	26	19.92		
Block	2	0.30		
N	2	5.23	2.61	6.21*
P	2	3.68	1.84	4.38*
K (mean)	1	2.13	2.13	5.07*
K (residual)	1	0.15	0.15	0.36
N x P (linear x linear)	1	1.61	1.61	3.83
N x K (linear x linear)	1	0.48	0.48	1.14
P x K (linear x linear)	1	0.05	0.05	0.12
Error	15	6.29	0.42	

Table 197 /

Table 197. Mean number of leaves per plant 3 weeks after singling, 1961.

1. Levels of nitrogen

n_o = 11.0

n_1 = 11.9 S.E. ±0.22

n_2 = 12.0

2. Levels of phosphorus

p_o = 11.1

p_1 = 11.8 S.E. = ±0.22

p_2 = 12.0

3. Levels of potassium

k_o = 11.2

k_1 = 11.7 S.E. = ±0.22

k_2 = 11.9

4. Nitrogen x phosphorus

	n_o	n_1	n_2	
p_o	10.8	11.3	11.2	
p_1	11.3	12.0	12.0	S.E. = ±0.38
p_2	10.9	12.3	12.8	

5. Nitrogen x potassium

	n_o	n_1	n_2	
k_o	11.1	11.2	11.3	
k_1	10.8	11.8	12.6	S.E. = ±0.38
k_2	11.1	12.6	12.1	

6. Phosphorus x potassium

	p_o	p_1	p_2	
k_0	10.7	11.5	11.4	
k_1	11.3	11.6	12.3	S.E. = ±0.38
k_2	11.3	12.2	12.2	

Table 198 /

APPENDIX B

Statistical Analysis - Section IVE

(The effect of weeds)

Table 198. Yield of sound roots, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	40604.67		
Replicates	2	2150.95		
Blocks/replicates	9	15534.22		
Weeding (W)	3	6478.25	2159.41	5.36***
Spacing (S)	3	3044.46	1014.82	2.52
W x S	9	4935.26	548.36	1.36
Error	21	8461.53	402.93	

Table 199. Yield of sound roots, 1959. Weeding x spacing (unadjusted) (tons per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	25.3	26.9	25.3	24.3	
8 inches	27.4	27.7	25.9	23.1	S.E. = ±0.83
11 inches	28.5	27.6	26.1	26.0	
14 inches	25.5	25.9	26.8	26.1	

Table 200 /

Table 200. Yield of sound roots, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	63029		
Replicates	2	4739		
Blocks/replicates	9	14615		
Weeding (W)	3	2490	830	1.23
Spacing (S)	3	6539	2180	3.24*
W x S	9	20539	2282	3.39*
Error	21	14107	672	

Table 201. Yield of sound roots, 1960. Weeding x spacing (unadjusted) (tons per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	43.4	43.3	42.7	45.1	
8 inches	43.9	43.1	43.9	45.1	S.E. = ±1.08
11 inches	41.0	46.4	44.2	41.0	
14 inches	45.4	41.4	38.1	42.3	

Table 202 /

Table 202. Yield of sound roots, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	86190.92		
Replicates	2	3082.07		
Blocks/replicates	9	13303.58		
Weeding (W)	3	39576.79	13192.26	13.72***
Spacing (S)	3	5616.12	1872.04	1.95
W x S	9	4416.11	490.68	0.49
Error	21	20196.25	961.73	

Table 203. Yield of sound roots, 1961. Weeding x spacing (unadjusted) (tons per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	39.0	40.8	41.3	36.6	
8 inches	40.6	40.0	38.8	34.6	S.E. = ±1.29
11 inches	41.1	39.1	36.1	33.0	
14 inches	39.0	40.3	37.1	35.5	

Table 204 /

Table 204. Yield of dry matter in the roots, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	371.42		
Blocks	11	125.07		
Weeding (W)	3	83.31	27.77	9.20^{**}
Spacing (S)	3	23.92	7.97	2.64
W x S	9	75.75	8.42	2.78^{*}
Error	21	63.37	3.02	

Table 205. Yield of dry matter in the roots, 1959. Weeding x spacing (unadjusted) (Cwt. per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	56.2	59.5	57.7	56.1	
8 inches	59.5	61.2	56.9	51.4	S.E. = ±1.44
11 inches	62.3	60.0	57.4	54.8	
14 inches	54.6	56.2	57.8	54.0	

Table 206. /

Table 206. Yield of dry matter in the roots, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	759.14		
Blocks	11	192.75		
Weeding (W)	3	28.54	9.51	1.09
Spacing (S)	3	206.31	68.77	7.88***
W x S	9	148.13	16.46	1.89
Error	21	183.41	8.73	

Table 207. Yield of dry matter in the roots, 1960. Weeding x spacing (unadjusted) (Cwt. per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	84.0	86.5	82.8	88.5	
8 inches	82.5	83.9	85.2	87.4	S.E. = ±2.4
11 inches	76.9	86.7	84.5	79.3	
14 inches	82.9	77.9	72.2	78.5	

Table 208 /

Table 208. Yield of dry matter in the roots, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	822.97		
Blocks	11	54.69		
Weeding (W)	3	222.74	74.25	4.37*
Spacing (S)	3	117.57	39.19	2.31
W x S	9	70.92	7.88	0.46
Error	21	357.05	17.00	

Table 209. Yield of dry matter in the roots, 1961. Weeding x spacing (unadjusted) (Cwt. per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	75.9	80.3	81.0	73.7	
8 inches	81.1	78.2	75.6	69.7	S.E. = ±3.4
11 inches	77.9	76.9	69.9	67.0	
14 inches	76.8	73.7	68.3	70.4	

Table 210 /

Table 210. Dry matter percentage of the roots, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	8.6139		
Blocks	11	3.0318		
Weeding (W)	3	0.2222	0.0741	0.64
Spacing (S)	3	2.3985	0.7995	6.92**
W x S	9	0.5334	0.0593	0.51
Error	21	2.4280	0.1156	

Table 211. Dry matter percentage of the roots, 1959. Weeding x spacing (unadjusted).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	11.09	11.05	11.43	11.58	
8 inches	10.86	11.04	11.02	11.15	S.E. = ±0.18
11 inches	10.95	10.81	11.01	10.54	
14 inches	10.72	10.85	10.83	10.37	

Table 212 /

Table 212. Dry matter percentage of the roots, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	5.9068		
Blocks	11	1.6436		
Weeding (W)	3	0.3762	0.1254	1.25
Spacing (S)	3	1.3886	0.4629	4.60*
W x S	9	0.3847	0.0416	0.41
Error	21	2.1137	0.1006	

Table 213. Dry matter percentage of the roots, 1960. Weeding x spacing (unadjusted).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	9.68	10.00	9.69	9.78	
8 inches	9.39	9.72	9.70	9.70	S.E. = ±0.18
11 inches	9.40	9.35	9.54	9.66	
14 inches	9.15	9.41	9.46	9.29	

Table 214 /

Table 214. Dry matter percentage of the roots, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	9.9057		
Blocks	11	0.4257		
Weeding (W)	3	1.5135	0.5045	1.99
Spacing (S)	3	1.0145	0.3382	1.34
W x S	9	1.3878	0.1542	0.61
Error	21	5.5642	0.2529	

Table 215. Dry matter percentage of the roots, 1961. Weeding x spacing. (unadjusted).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	9.75	9.83	9.81	10.14	
8 inches	10.01	9.48	9.75	10.04	S.E. = $\pm$0.28
11 inches	9.37	9.86	9.68	10.16	
14 inches	9.84	9.13	9.23	9.97	

Table 216 /

Table 216. Yield of tops, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	5566.31		
Blocks	11	1810.68		
Weeding (W)	3	40.85	13.62	0.49
Spacing (S)	3	2647.43	882.48	31.46***
W x S	9	478.23	53.14	1.89
Error	21	589.12	28.05	

Table 217. Yield of tops, 1959. Weeding x spacing (unadjusted) (tons per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	5.0	4.8	4.3	4.8	
8 inches	3.7	3.6	4.4	3.7	S.E. = ±0.22
11 inches	3.5	3.7	3.7	3.8	
14 inches	3.1	3.3	3.6	3.0	

Table 218 /

Table 218. Yield of tops, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	17163.09		
Blocks	11	7579.56		
Weeding (W)	3	161.10	53.70	0.43
Spacing (S)	3	6733.40	2244.47	18.04^{***}
W x S	9	76.24	8.47	0.07
Error	21	2612.79	124.42	

Table 219. Yield of tops, 1960. Weeding x spacing (unadjusted) (tons per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	8.0	7.3	7.3	7.6	
8 inches	6.0	6.7	7.0	7.2	S.E. = $\pm$0.46
11 inches	5.6	5.6	6.1	6.0	
14 inches	5.5	5.4	5.1	5.6	

Table 220 /

Table 220. Yield of tops, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	8810.81		
Blocks	11	2105.84		
Weeding (W)	3	213.52	71.17	0.41
Spacing (S)	3	1897.35	632.45	3.66
W x S	9	962.01	106.89	0.62
Error	21	3632.09	172.96	

Table 221. Yield of tops, 1961. Weeding x spacing (unadjusted)(tons per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	4.49	4.90	4.37	4.40	
8 inches	3.53	3.60	3.92	3.60	S.E. = ±0.54
11 inches	3.53	2.78	3.06	4.12	
14 inches	2.59	4.39	3.68	3.44	

Table 222 /

Table 222. Post-singling plant count, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	123918		
Blocks	11	2678		
Weeding (W)	3	95	32	0.44
Spacing (S)	3	118975	39658	591.91***
W x S	9	752	83	1.24
Error	21	1418	67	

Table 223. Post-singling plant count, 1959. Weeding x spacing. (unadjusted) (Plants per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	38,933	36,462	36,946	36,677	
8 inches	24,809	26,582	26,635	27,011	S.E. = ±772
11 inches	20,191	20,782	19,976	19,386	
14 inches	14,660	15,788	17,453	16,003	

Table 224 /

Table 224. Post-singling plant count, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	129206		
Blocks	11	665		
Weeding (W)	3	811	270	2.94
Spacing (S)	3	125754	41918	455.63***
W x S	9	45	5	0.05
Error	21	1931	92	

Table 225. Post-singling plant count, 1960. Weeding x spacing. (unadjusted) (Plants per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	36,140	40,060	39,147	39,201	
8 inches	26,206	27,709	27,602	27,978	S.E. = ±902
11 inches	20,460	20,084	20,836	21,587	
14 inches	16,379	17,130	16,808	17,291	

Table 226 /

Table 226. Post-singling plant count, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	183878		
Blocks	11	819		
Weeding (W)	3	96	32	.28
Spacing (S)	3	179591	59863	529.76***
W x S	9	1009	112	.99
Error	21	2363	113	

Table 227. Post-singling plant count, 1961. Weeding x spacing. (unadjusted) (Plants per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	43,336	42,101	43,873	43,229	
8 inches	27,870	27,602	28,944	27,226	S.E. = ±966
11 inches	20,513	21,534	20,889	22,232	
14 inches	16,754	17,721	16,376	18,097	

Table 228 /

Table 228. Number of sound roots harvested, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	93606		
Blocks	11	3407		
Weeding (W)	3	574	191	2.42
Spacing (S)	3	87323	29108	368.40***
W x S	9	628	70	.88
Error	21	1674	79	

Table 229. Number of sound roots harvested, 1959. Weeding x spacing (unadjusted) (Roots per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	33,724	33,026	33,831	33,509	
8 inches	21,695	24,971	24,004	25,613	S.E. = ±838
11 inches	19,004	20,136	19,332	18,849	
14 inches	13,640	15,036	15,788	15,627	

Table 230 /

Table 230. Number of sound roots harvested, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	71944		
Blocks	11	600		
Weeding (W)	3	594	198	1.92
Spacing (S)	3	67614	22538	218.83***
W x S	9	983	109	1.06
Error	21	2153	103	

Table 231. Number of sound roots harvest, 1960. Weeding x spacing. (unadjusted) (Roots per acre)

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	29,481	31,361	32,596	30,878	
8 inches	23,091	24,595	24,487	24,272	S.E. = ±934
11 inches	17,184	18,473	18,204	19,601	
14 inches	15,143	15,466	14,231	15,950	

Table 232 /

Table 232. Number of sound roots harvested, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	132732		
Blocks	11	1757		
Weeding (W)	3	354	118	1.30
Spacing (S)	3	127410	42470	466.71***
W x S	9	1308	145	1.59
Error	21	1903	91	

Table 233. Number of sound roots harvested, 1961. Weeding x spacing. (unadjusted) (roots per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	41,188	38,127	37,805	38,503	
8 inches	27,011	24,917	26,850	27,065	S.E. = ±870
11 inches	20,245	21,158	20,299	21,158	
14 inches	16,540	17,077	16,432	17,936	

Table 234 /

Table 234. Yield of diseased roots, 1959. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	5575.17		
Blocks	11	944.55		
Weeding (W)	3	1199.13	399.71	4.33*
Spacing (S)	3	1043.04	347.68	3.77*
W x S	9	451.86	50.21	0.54
Error	21	1936.59	92.22	

Table 235. Yield of diseased roots, 1959. Weeding x spacing.
(unadjusted) (cwt. per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	3.6	1.9	3.1	5.0	
8 inches	22.3	7.7	17.0	0.7	S.E. = ±8.06
11 inches	32.6	10.3	19.2	8.9	
14 inches	38.4	12.0	24.5	9.6	

Table 236 /

Table 236. Yield of diseased roots, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	12633.45		
Blocks	11	3210.13		
Weeding (W)	3	952.09	317.36	3.04*
Spacing (S)	3	4404.68	1468.23	14.07***
W x S	9	1876.10	208.45	1.99
Error	21	2190.45	104.31	

Table 237. Yield of diseased roots, 1960. Weeding x spacing.
(unadjusted) (cwt. per acre).

	Weeded at singling	Weeded 2 weeks after singling	Weeded 4 weeks after singling	Unweeded	
5 inches	12.0	25.0	5.3	4.6	
8 inches	24.2	20.2	9.1	8.6	S.E. = $\pm$8.80
11 inches	47.5	17.3	27.8	18.2	
14 inches	38.4	38.2	82.6	29.3	

Table 238 /

APPENDIX B

Statistical Analysis - Section IVE

(Couped V Uncouped).

Table 238. Yield of sound roots (Couped V Uncouped), 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	23	31072		
Blocks	2	6424		
Spacing (S)	3	3069	1023	1.95
Couping (C)	1	8438	8438	16.10^{***}
S x C	3	5797	1932	3.69^{*}
Error	14	7344	524	

Table 239. Yield of sound roots (Couped V Uncouped, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	23	24855.99		
Blocks	2	5504.02		
Spacing (S)	3	3854.94	1284.98	1.63
Couping (C)	1	2390.01	2390.01	3.03
S x C	3	2081.87	693.95	0.88
Error	14	11025.15	787.51	

Table 240 /

Table 240. Yield of sound roots (Couped V Uncouped), 1961. Couping x spacing (tons per acre).

	Uncouped	Couped	
5 inches	39.1	39.4	
8 inches	40.6	37.4	S.E. = ± 1.16
11 inches	41.1	40.0	
14 inches	39.0	37.0	

Table 241. Yield of dry matter (Couped V Uncouped), 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	23	306.95		
Blocks	2	39.12		
Spacing (S)	3	57.93	19.31	3.00
Couping (C)	1	74.55	74.55	11.59***
S x C	3	45.38	15.13	2.35
Error	14	89.97	6.43	

Table 242. Yield of dry matter (Couped V Uncouped), 1960. Couping x spacing (cwt. per acre).

	Uncouped	Couped	
5 inches	84.0	79.4	
8 inches	82.5	79.1	S.E. = ± 2.0
11 inches	76.9	76.1	
14 inches	82.9	71.4	

Table 243. Yield of dry matter (Couped V Uncouped), 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	23	434.03		
Blocks	2	75.83		
Spacing (S)	3	24.21	8.07	0.61
Couping (C)	1	34.56	34.56	2.60
S x C	3	113.59	37.86	2.85
Error	14	185.84	13.27	

Table 244. Yield of dry matter (Couped V Uncouped), 1961. Couping x spacing (cwt. per acre).

	Uncouped	Couped	
5 inches	75.9	79.8	
8 inches	81.1	67.8	S.E. = ± 3.0
11 inches	77.9	76.9	
14 inches	76.8	73.5	

Table 245. /

Table 245. Dry matter percentage of the roots (Couped v Uncouped), 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	23	2.5711		
Blocks	2	0.6184		
Spacing (S)	3	0.5719	0.1906	2.04
Couping (C)	1	0.0009	0.0009	0.009
S x C	3	0.0714	0.0238	0.25
Error	14	1.3085	0.0935	

Table 246. Dry matter percentage of the roots (Couped V Uncouped), 1960. Couping x spacing.

	Uncouped	Couped	
5 inches	9.68	9.49	
8 inches	9.39	9.50	S.E. = ± 0.18
11 inches	9.40	9.41	
14 inches	9.15	9.17	

Table 247 /

Table 247. Dry matter percentage of the roots (Couped V Uncouped), 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	23	5.6096		
Blocks	2	0.8107		
Spacing (S)	3	0.6886	0.2295	1.61
Couping (C)	1	0.3800	0.3800	2.66
S x C	3	1.7334	0.5778	$4.05^{\underline{x}}$
Error	14	1.9969	0.1426	

Table 248. Dry matter percentage of the roots (Couped V Uncouped), 1961. Couping x spacing.

	Uncouped	Couped	
5 inches	9.75	10.12	
8 inches	10.01	9.04	S.E. = ± 0.22
11 inches	9.47	9.62	
14 inches	9.84	9.28	

Table 249 /

Table 249. Yield of tops (Couped V Uncouped), 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	23	8232.49		
Blocks	2	3380.77		
Spacing (S)	3	3157.95	1052.65	10.49***
Couping (C)	1	31.51	31.51	0.32
S x C	3	296.70	98.90	1.01
Error	14	1365.56	97.54	

Table 250. Yield of tops (Couped V Uncouped), 1960. Couping x spacing (tons per acre).

	Uncouped	Couped	
5 inches	8.03	7.06	
8 inches	6.05	6.46	S.E. = ± 0.42
11 inches	5.60	5.46	
18 inches	5.48	5.53	

Table 251 /

Table 251. Yield of tops (Couped V Uncouped), 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	23	4445.33		
Blocks	2	634.08		
Spacing (S)	3	2438.58	812.86	8.54***
Couping (C)	1	1.50	1.50	0.015
S x C	3	38.75	12.92	0.14
Error	14	1332.32	95.16	

Table 252. Yield of tops (Couped V Uncouped), 1961. Couping x spacing (tons per acre).

	Uncouped	Couped	
5 inches	4.49	4.72	
8 inches	3.53	3.50	S.E. = ± 0.41
11 inches	3.53	3.24	
14 inches	2.59	2.53	

Table 253 /

Table 253. Post-singling plant count (Couped V Uncouped), 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	23	46619		
Blocks	2	78		
Spacing (S)	3	45153	15051	320.10***
Couping (C)	1	400	400	8.51*
S x C	3	331	110	2.34
Error	14	657	47	

Table 254. Post-singling plant count (Couped V Uncouped), 1960. Couping x spacing (plants per acre).

	Uncouped	Couped	
5 inches	36,140	32,811	
8 inches	26,206	25,991	S.E. = ± 644
11 inches	20,460	19,762	
14 inches	16,379	15,358	

Table 255 /

Table 255. Post-singling plant count (Couped V Uncouped), 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	23	94816		
Blocks	2	203		
Spacing (S)	3	93518	31194	495.14***
Couping (C)	1	131	131	2.08
S x C	3	21	7	0.11
Error	14	880	63	

Table 256. Post-singling plant count (Couped V Uncouped), 1961. Couping x spacing (plants per acre).

	Uncouped	Couped	
5 inches	43,336	42,316	
8 inches	27,870	26,850	S.E. = ± 742
11 inches	20,513	19,815	
14 inches	16,754	16,486	

Table 257 /

Table 257. Number of sound roots harvested (Couped V Uncouped), 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	23	28289		
Blocks	2	46		
Spacing (S)	3	26671	8890	98.77***
Couping (C)	1	145	145	1.61
S x C	3	164	55	0.61
Error	14	1263	90	

Table 258. Number of sound roots harvest (Couped V Uncouped), 1960. Couping x spacing (roots per acre).

	Uncouped	Couped	
5 inches	29,481	27,656	
8 inches	23,091	22,540	S.E. = ± 870
11 inches	17,184	17,614	
14 inches	15,143	13,908	

Table 259 /

Table 259. Number of sound roots harvested (Couped V Uncouped), 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	23	79296		
Blocks	2	1077		
Spacing (S)	3	75148	25049	191.21***
Couping (C)	1	988	988	7.54*
S x C	3	251	84	0.64
Error	14	1832	131	

Table 260. Number of sound roots harvested (Couped and Uncouped), 1961. Couping x spacing (roots per acre).

	Uncouped	Couped	
5 inches	41,188	37,859	
8 inches	27,011	25,239	S.E. = ± 1062
11 inches	20,245	17,614	
14 inches	16,540	16,003	

Table 261 /

APPENDIX B

Statistical Analysis - Section IVF.

(The effect of exposing the hypocotyl
and the effect of the method of sowing)

Table 261. Yield of sound roots, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	81352		
Replicates	3	7437		
Stage of singling (S)	1	8112	8112	5.17*
Method of sowing (M)	2	3003	1501	0.99
Method of singling (C)	1	4721	4721	3.01
S x M	2	2856	1428	0.95
M x C	2	1098	549	0.36
S x C	1	1496	1496	0.99
S x M x C	2	808	404	0.27
Error	33	51823	1507	

Table 262. Yield of sound roots, 1960. Two-way tables (tons per acre)

	Uncouped	Couped		1st singling	2nd singling	
Turnip barrow	40.6	38.7		39.5	39.8	
Precision seeder	38.9	38.4	S.E. = $\pm$0.84	37.5	39.8	S.E. = $\pm$0.84
Precision seeder with notched roller	39.2	38.0		37.5	39.7	

	1st singling	2nd singling	
Uncouped	38.5	40.7	S.E. = $\pm$ 0.68
Couped	37.9	38.8	

Table 263. Yield of Dry Matter, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	1025.02		
Replicates	3	119.96		
Stage of singling (S)	1	44.85	44.85	2.20
Method of Sowing (M)	2	16.63	8.31	0.41
Method of Singling (C)	1	52.50	52.50	2.57
S x M	2	48.70	24.35	1.19
M x C	2	36.00	18.00	0.88
S x C	1	30.09	30.09	1.47
S x M x C	2	1.94	0.97	0.048
Error	33	674.35	20.43	

Table 264. Yield of Dry Matter, 1960. Two-way tables (tons per acre).

	Uncouped	Couped		1st Singling	2nd Singling	
Turnip barrow	78.8	73.4		76.6	75.6	
Precision seeder	76.0	75.0	S.E. = ±1.80	73.0	77.8	S.E. = ±1.80
Precision seeder with notched roller	75.0	73.8		72.8	75.8	

	1st singling	2nd singling	
Uncouped	74.4	78.6	S.E. = ±1.56
Couped	73.8	74.2	

Table 265 /

Table 265. Dry matter percentage of the roots, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	3.9439		
Replicates	3	0.8244		
Stage of Singling (S)	1	0.0744	0.0744	1.05
Method of Sowing (M)	2	0.2632	0.1316	1.85
Method of Singling (C)	1	0.0054	0.0054	0.08
S x M	2	0.0744	0.0372	0.52
M x C	2	0.0281	0.0140	0.20
S x C	1	0.0475	0.0237	0.33
S x M x C	2	0.2877	0.1439	2.03
Error	33	2.3388	0.0709	

Table 266. Dry Matter percentage of the roots, 1960. Two-way tables.

	Uncouped	Couped		1st singling	2nd singling	
Turnip barrow	9.69	9.48		9.66	9.51	
Precision seeder	9.75	9.77	S.E. = $\pm$.09	9.75	9.78	S.E. = $\pm$.09
Precision seeder with notched roller	9.56	9.70		9.69	9.57	

	1st singling	2nd singling	
Uncouped	9.68	9.66	S.E. = $\pm$.08
Couped	9.72	9.58	

Table 267 /

Table 267. Yield of Tops, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	6087.24		
Replicates	3	2934.64		
Stage of Singling (S)	1	0.42	0.42	0.01
Method of Sowing (M)	2	11.94	5.97	0.08
Method of Singling (C)	1	84.00	84.00	1.21
M x S	2	176.85	88.43	1.27
M x C	2	344.46	172.23	2.47
S x C	1	131.67	131.67	1.89
S x M x C	2	106.59	53.29	0.77
Error	33	2296.67	69.60	

Table 268. Yield of tops, 1960. Two-way tables (tons per acre).

	Uncouped	Couped		1st Singling	2nd Singling	
Turnip barrow	3.66	3.74		3.74	3.65	
Precision seeder	3.72	3.53	S.E. = ±.17	3.73	3.52	S.E. = ±.17
Precision seeder with notched roller	3.36	3.95		3.49	3.82	

	1st singling	2nd singling	
Uncouped	3.46	3.69	S.E. = ±.14
Couped	3.82	3.65	

Table 269 /

Table 269. Post-singling plant count, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	5464		
Replicates	3	377		
Stage of Singling (S)	1	954	954	11.49***
Method of Sowing (M)	2	662	331	3.98*
Method of Singling (C)	2	331	331	3.98
M x S	2	19	9	0.11
M x C	2	130	65	0.78
S x C	1	44	44	0.55
M x S x C	2	207	103	1.24
Error	33	2740	83	

Table 270. Post-singling plant count, 1960. Two-way table (plants per acre).

	Uncouped	Couped		1st Singling	2nd Singling	
Turnip barrow	19,118	19,572		18,866	19,824	
Precision seeder	17,976	18,312	S.E. = ±430	17,489	18,799	S.E. = ±430
Precision seeder with notched roller	18,278	19,606		18,278	19,605	

	1st singling	2nd singling	
Uncouped	17,987	18,928	S.E. = ±349
Couped	18,435	19,891	

Table 271 /

Table 271. Number of sound roots harvested, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	47	6319		
Replicates	3	874		
Stage of Singling (S)	1	784	784	8.00***
Method of Sowing (M)	2	1108	504	5.14*
Method of Singling (C)	1	108	108	1.10
M x S	2	115	57	0.58
M x C	2	31	15	15.31
S x C	1	1	1	0.01
M x S x C	2	67	33	0.34
Error	33	3231	98	

Table 272. Number of sound roots harvested, 1960. Two-way tables (roots per ac

	Uncouped	Couped		1st Singling	2nd Singling	
Turnip barrow	17,270	17,539		17,153	17,657	
Precision seeder	15,775	16,010	S.E. = ±484	15,170	16,615	S.E. = ±484
Precision seeder with notched roller	16,699	17,405		16,397	17,702	

	1st singling	2nd singling	
Uncouped	16,016	17,147	S.E. = ±390
Couped	16,464	17,506	

Table 273 /

Table 273. Yield of sound roots, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Replicates	3	8475.1		
Method of Sowing (M)	2	48228.3	24114.1	5.49^{*}
Error (a)	6	26349.1	4391.5	
Main plots	11	83052.5		
Stage of Singling (S)	1	7503.2	7503.2	9.36^{**}
Method of Singling (C)	2	8393.2	4196.6	5.23^{**}
S x C	2	2280.2	1140.1	1.42
S x M	2	2206.7	1103.4	1.38
M x C	4	4153.8	1038.5	1.29
S x M x C	4	2438.4	609.6	0.76
Error (b)	45	36076.9	801.7	
Total	71	146104.9		

Table 274. Yield of sound roots, 1961. Two-way tables. (tons per acre).

	Uncouped	Couped	Singled by hoe		1st Singling	2nd Singling	
Turnip barrow	38.3	39.4	36.5		39.3	36.8	
Precision seeder	37.1	37.5	35.2	S.E. = ±0.72	37.3	36.0	S.E. = ±0.58
Precision seeder with notched roller	34.2	33.3	33.3		33.9	33.3	

	1st singling	2nd singling	
Uncouped	36.9	36.2	
Couped	37.2	36.2	S.E. = ±0.58
Singled by hoe	36.3	33.7	

Table 275 /

Table 275. Yield of Dry Matter, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Replicates	3	92.16		
Method of Sowing (M)	2	303.92	151.96	3.23
Error (a)	6	282.46	47.08	
Main Plots	11	678.54		
Stage of Singling (S)	1	86.68	86.68	7.43***
Method of Singling (C)	2	78.34	39.14	3.36*
S x C	2	48.34	24.14	2.07
S x M	2	12.54	6.27	0.54
M x C	4	55.62	13.91	1.19
S x M x C	4	84.92	21.23	1.82
Error (b)	45	524.85	11.66	
Total	71	1569.83		

Table 276. Yield of dry matter, 1961. Two-way tables. (Cwt.per acre).

	Uncouped	Couped	Singled by hoe		1st Singling	2nd Singling	
Turnip barrow	75.3	74.3	68.8		75.2	70.4	
Precision seeder	70.2	71.6	67.3	S.E. = ±1.74	71.0	68.4	S.E. = ±1.43
Precision seeder with notched roller	65.3	65.8	65.7		66.6	64.5	

	1st singling	2nd singling	
Uncouped	70.2	70.3	
Couped	72.9	68.3	S.E. = ±1.43
Singled by hoe	69.7	64.7	

Table 277 /

Table 277. Dry matter percentage of the roots, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Replicates	3	1.0780		
Method of Sowing (M)	2	0.9293	0.4647	4.92
Error (a)	6	0.5658	0.0943	
Main Plots	11	2.5731		
Stage of Singling (S)	1	0.0807	0.0807	
Method of Singling (C)	2	0.0456	0.0228	0.10
S x C	2	0.7869	0.3935	1.79
S x M	2	0.1462	0.0731	0.33
M x C	4	1.0414	0.2603	1.18
S x M x C	4	2.1875	0.5469	2.49
Error (b)	45	9.8945	0.2199	
Total	71	16.7559		

Table 278. Dry matter percentage of the roots, 1961. Two-way tables.

	Uncouped	Couped	Singled by hoe		1st singling	2nd singling	
Turnip barrow	9.84	9.43	9.44		9.56	9.57	
Precision seeder	9.46	9.53	9.56	S.E. = ±.17	9.53	9.51	S.E. = ±.13
Precision seeder with notched roller	9.67	9.82	9.85		9.88	9.68	

	1st singling	2nd singling	
Uncouped	9.58	9.73	
Couped	9.77	9.42	S.E. = ±.13
Singled by hoe	9.62	9.62	

Table 279 /

Table 279. Yield of Tops, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Replicates	3	1122.03		
Method of Sowing (M)	2	99.25	49.63	0.30
Error (a)	6	996.72	166.12	
Main Plots	11	2218.00		
Stage of Singling (S)	1	4.01	4.01	0.08
Method of Singling (C)	2	24.02	12.01	0.23
S x C	2	57.47	28.73	0.55
S x M	2	117.87	53.93	1.04
M x C	4	213.48	53.37	1.03
S x M x C	4	97.15	24.29	0.47
Error (b)	45	2335.50	51.90	
Total	71	5067.50		

Table 280. Yield of tops, 1961. Two-way tables (tons per acre).

	Uncouped	Couped	Singled by hoe		1st Singling	2nd Singling	
Turnip barrow	3.95	3.66	3.54		3.60	3.83	
Precision seeder	3.89	4.07	3.81	S.E. = ±.18	4.02	3.82	S.E. = ±.75
Precision seeder with notched roller	3.68	3.83	3.93		3.87	3.75	

	1st singling	2nd singling	
Uncouped	3.78	3.90	
Couped	3.87	3.83	S.E. = ±.75
Singled by hoe	3.85	3.66	

Table 281 /

Table 281. Post-singling plant count, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Replicates	3	44		
Method of Sowing (M)	2	97	49	1.04
Error (a)	6	284	47	
Main Plots	11	425		
Stage of Singling (S)	1	939	939	30.29***
Method of Singling (C)	2	3630	1815	58.54***
S x C	2	368	184	5.93***
S x M	2	19	9	0.29
M x C	4	186	47	1.52
S x M x C	4	90	23	0.74
Error (b)	45	1421	31	
Total	71	7078		

Table 282. Post-singling plant Count, 1961. Two-way tables (plants per acre).

	Uncouped	Couped	Singled by hoe		1st Singling	2nd Singling	
Turnip barrow	25,364	24,277	22,042		23,195	24,522	
Precision seeder	25,646	24,659	22,666	S.E. = ±317	23,678	24,897	S.E. = ±258
Precision seeder with notched roller	25,263	24,236	23,250		23,745	24,683	

Table 283 /

Table 283. Number of sound roots at harvest, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Replicates	3	456		
Method of Sowing (M)	2	134	67	0.62
Error (a)	6	648	108	
Main Plots	11	1238		
Stage of Singling (S)	1	1395	1395	26.82***
Method of Singling (C)	2	3118	1559	29.98***
S x C	2	399	199	3.83
S x M	2	168	84	1.61
M x C	4	139	35	0.67
S x M x C	4	90	23	0.44
Error (b)	45	2333	52	
Total	71	8880		

Table 284. Number of sound roots harvested. Two-way table (roots per acre).

	Uncouped	Couped	Singled by hoe		1st Singling	2nd Singling	
Turnip barrow	24,156	23,190	20,975		21,922	23,557	
Precision seeder	24,297	23,471	21,901	S.E. = ±410	22,820	23,557	S.E. = ±335
Precision seeder with notched roller	24,337	23,230	22,203		22,284	24,160	

Table 285 /

APPENDIX B

Statistical Analysis - Section IVG

(The effect of plant population and plant distribution)

Table 285. Yield of sound roots, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	35	36828		
Replicates	3	11010		
Spacing (S)	2	2972	1486	2.16
Distribution (D)	2	4547	2273	3.31
S x D	4	1811	453	0.66
Error	24	16488	687	

Table 286. Yield of sound roots, 1960. Spacing x distribution (tons per acre).

	Regular	$\frac{1}{8}$ Irregular	Very Irregular	
8 inches	40.6	37.7	39.2	
12 inches	40.4	40.1	39.5	S.E. = $\pm$ 0.94
16 inches	39.9	37.6	37.8	

Table 287 /

Table 287. Yield of sound roots, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	53	26597.86		
Replicates	5	3240.71		
Spacing (S)	2	1900.73	950.37	1.86
Distribution (D)	2	585.73	292.86	0.57
S x D	4	425.35	106.34	0.28
Error	40	20445.34	511.13	

Table 288. Yield of sound roots, 1961. Spacing x distribution (tons per acre).

	Regular	$\frac{1}{8}$ Irregular	Very Irregular	
8 inches	32.7	33.7	32.8	
12 inches	32.9	33.1	32.7	S.E. = ± 0.66
16 inches	32.3	32.2	31.8	

Table 289. Yield of dry matter, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	35	429.15		
Replicates	3	53.38		
Spacing (S)	2	68.08	34.04	3.61*
Distribution (D)	2	65.87	32.93	3.49*
S x D	4	15.23	3.81	0.40
Error	24	226.59	9.44	

Table 290. Yield of dry matter, 1960. Spacing x distribution (cwt. per acre).

	Regular	½ Irregular	Very Irregular	
8 inches	86.0	78.6	84.1	
12 inches	84.3	81.5	82.6	S.E. = ± 2.19
16 inches	80.7	76.8	78.4	

Table 291. Yield of dry matter, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	53	462.76		
Replicates	5	19.47		
Spacing (S)	2	25.48	12.74	1.26
Distribution (D)	2	4.27	2.13	0.21
S x D	4	8.33	2.08	0.20
Error	40	405.21	10.13	

Table 292. Yield of dry matter, 1961. Spacing x distribution (cwt. per acre).

	Regular	½ Irregular	Very Irregular	
8 inches	64.0	62.8	62.1	
12 inches	61.6	62.5	62.5	S.E. = ± 1.87
16 inches	61.6	60.6	59.7	

Table 293 /

Table 293. Dry matter percentage of the roots, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	35	3.6047		
Replicates	3	0.4484		
Spacing (S)	2	0.7093	0.3547	4.12*
Distribution (D)	2	0.2737	0.1369	1.59
S x D	4	0.1055	0.0264	0.31
Error	24	2.0678	0.0861	

Table 294. Dry matter percentage of the roots, 1960. Spacing x distribution.

	Regular	$\frac{1}{2}$ Irregular	Very Irregular	
8 inches	10.58	10.43	10.72	
12 inches	10.42	10.25	10.45	S.E. = ± 0.14
16 inches	10.12	10.22	10.37	

Table 295. Dry matter percentage of the roots, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	53	10.1952		
Replicates	5	0.9114		
Spacing (S)	2	0.1087	0.0543	0.26
Distribution (D)	2	0.3406	0.1703	0.81
S x D	4	0.4515	0.1129	0.54
Error	40	8.3830	0.2096	

Table 296. Dry matter percentage of the roots, 1961. Spacing x Distribution.

	Regular	$\frac{1}{2}$ Irregular	Very Irregular	
8 inches	9.78	9.31	9.46	
12 inches	9.38	9.44	9.41	S.E. = $\pm$ 0.19
16 inches	9.52	9.43	9.37	

Table 297. Post-singling plant count, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	35	32200		
Replicates	3	119		
Spacing (S)	2	30646	15323	312.71***
Distribution (D)	2	68	34	0.69
S x D	4	178	45	0.92
Error	24	1189	49	

Table 298. Post-singling plant count, 1960. Spacing x distribution (plants per acre).

	Regular	$\frac{1}{2}$ Irregular	Very Irregular	
8 inches	27,571	28,457	26,806	
12 inches	19,521	19,360	19,682	S.E. = $\pm$ 563
16 inches	16,140	16,704	16,543	

Table 299 /

Table 299. Post-singling plant count, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	53	57185		
Replicates	5	124		
Spacing (S)	2	56434	28217.0	2637.11***
Distribution (D)	2	24	112.0	1.12
S x D	4	173	43.2	4.04***
Error	40	430	10.7	

Table 300. Yield of diseased roots, 1960. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	35	3148.22		
Replicates	3	413.77		
Spacing (S)	2	507.72	253.86	3.60*
Distribution (D)	2	337.05	168.53	2.39
S x D	4	199.45	49.86	0.71
Error	24	1690.23	70.43	

Table 301 /

Table 301. Yield of diseased roots, 1960. Spacing x distribution (cwt. per acre).

	Regular	½ Irregular	Very Irregular	
8 inches	13.0	16.9	10.8	
12 inches	10.4	30.2	16.9	S.E. = ± 6.0
16 inches	28.4	31.0	20.9	

Table 302. Yield of diseased roots, 1961. Analysis of Variance.

Source	d.f.	SS	MS	VR
Total	53	11022.5		
Replicates	5	840.5		
Spacing (S)	2	3079.7	1539.9	9.97**
Distribution (D)	2	92.4	46.2	0.30
S x D	4	838.8	209.7	1.36
Error	40	6171.1	154.3	

Table 303. Yield of diseased roots, 1961. Spacing x distribution (cwt. per acre).

	Regular	½ Irregular	Very Irregular	
8 inches	14.7	11.6	12.4	
12 inches	10.1	34.0	25.1	S.E. = ± 5.0
16 inches	43.0	35.9	39.1	

APPENDIX C

Details of Digestibility Trials

Table 304. The weight of dry matter fed, the weight consumed and the mean daily dry matter intake - 1960.

Sheep	P	Q	R	T	U
Weight fed (gm.)	6932.5	5947.3	5824.1	5630.9	8849.2
Weight residue (gm)	615.1	596.2	2088.0	733.8	1720.5
Weight consumed (gm.)	6317.4	5351.1	3736.1	4897.1	7128.7
Mean dry matter intake per day (lb.)	1.4	1.2	0.8	1.1	1.6

Table 305. The weight of dry matter fed, the weight consumed and the mean daily dry matter intake - 1961.

Sheep	F	L	G	H
Weight fed (gm.)	7374.3	7830.8	8776.0	7898.4
Weight residue (gm.)	2329.0	706.0	337.5	1159.5
Weight consumed (gm.)	5045.3	7124.8	8438.5	6738.9
Mean dry matter intake per day (lb.)	1.1	1.6	1.8	1.5

Table 306 /

Table 306. Digestibility Coefficients, 1960.

Sheep P. (Small roots).

	1	2	3	4		
	Weight eaten gm.	Analysis of feed per cent.	Weight of faeces gm.	Analysis of faeces per cent.	1 - 3	Digestibility Coefficient
DM	6317.4		1137.7		5179.7	81.99
OM	5975.6	94.59	937.1	82.37	5038.5	84.32
CP	454.9	7.20	271.7	23.88	183.2	40.27
EE	37.9	0.60	30.9	2.72	7.0	18.47
CF	781.5	12.37	319.8	28.11	461.7	59.08
NFE	4701.4	74.42	314.7	27.66	4386.7	93.31
Ash	341.8	5.41	200.6	17.63		

Sheep Q. (Small roots).

DM	5351.1		974.0		4377.1	81.80
OM	5057.3	94.51	807.0	82.85	4250.3	84.04
CP	379.9	7.10	215.0	22.07	164.9	43.41
EE	31.0	0.58	17.6	1.81	13.4	43.23
CF	687.1	12.84	274.8	28.21	412.3	60.01
NFE	3959.3	73.99	299.6	30.76	3659.7	92.43
Ash	293.8	5.49	167.0	17.15		

Table 306 (Continued)

Sheep R. (Small Roots)

	1 Weight eaten gm.	2 Analysis of feed per cent.	3 Weight of faeces gm.	4 Analysis of faeces per cent.	1 - 3	Digestibility Coefficient
DM	3731.1		625.6		3110.5	83.26
OM	3541.1	94.78	512.0	81.84	3029.1	85.54
CP	259.3	6.94	139.0	22.22	120.3	46.39
EE	24.7	0.66	12.8	2.04	11.9	48.18
CF	486.1	13.01	160.2	25.60	325.9	67.04
NFE	2771.1	74.17	200.1	31.98	2571.0	92.78
Ash	195.0	5.22	113.6	18.16		

Sheep T. (Large Roots)

DM	4897.1		446.4		4450.7	90.88
OM	4596.7	93.87	332.8	74.56	4264.1	92.76
CP	395.2	8.07	94.0	21.06	301.2	76.21
EE	24.5	0.50	12.4	2.78	12.1	49.39
CF	557.3	11.38	101.3	22.69	456.0	81.82
NFE	3619.9	73.92	125.1	28.03	3494.8	96.54
Ash	300.2	6.13	113.6	25.44		

Table 306 (Continued).

Sheep U. (Large Roots)

	1 Weight eaten gm.	2 Analysis of feed per cent.	3 Weight of faeces gm.	4 Analysis of faeces per cent.	1 - 3	Digestibility Coefficient
DM	7128.7		989.8		6138.9	86.12
OM	6671.8	93.59	789.4	79.75	5882.4	88.17
CP	628.8	8.82	296.4	29.95	332.4	52.86
EE	47.0	0.66	26.0	2.63	21.0	44.68
CF	784.9	11.01	164.1	16.58	620.8	79.09
NFE	5211.1	73.10	302.8	30.59	4908.3	94.19
Ash	456.9	6.41	200.4	20.25		

Table 307. Digestibility Coefficients, 1961.

Sheep F. (Small roots)

	Weight eaten gm.	Analysis of feed per cent.	Weight of faeces gm.	Analysis of faeces per cent.	1 - 3	Digestibility Coefficient
DM	5045.3		640.0		4405.3	87.31
OM	4708.8	93.33	470.5	73.51	4238.3	90.01
CP	618.0	12.25	152.9	23.89	465.1	75.26
EE	31.8	0.63	14.1	2.20	17.7	55.66
CF	572.6	11.35	133.5	20.86	439.1	76.69
NFE	3486.3	69.10	170.0	26.56	3316.3	95.12
Ash	336.5	6.67	169.5	26.49		

Table 307. (Continued).

Sheep K. (Small Roots.)

	1	2	3	4		
	Weight eaten gm.	Analysis of feed per cent.	Weight of faeces gm.	Analysis of faeces per cent.	1 - 3	Digestibility Coefficient
DM	7387.5		740.2		6647.3	89.98
OM	6894.7	93.33	564.2	76.23	6330.5	91.82
CP	905.0	12.25	200.8	27.13	704.2	77.81
EE	46.5	0.63	17.8	2.40	18.7	40.22
CF	838.5	11.35	132.3	17.88	706.2	84.22
NFE	5104.8	69.10	213.3	28.82	4891.5	95.82
Ash	492.7	6.67	175.9	23.77		

Sheep L. (Small Roots)

DM	7124.8		897.7		6227.1	87.40
OM	6649.6	93.33	639.7	71.26	6009.9	90.38
CP	872.8	12.25	234.8	26.16	638.0	73.10
EE	44.9	0.63	24.6	2.74	20.3	45.21
CF	808.7	11.35	141.9	15.81	666.8	82.45
NFE	4923.2	69.10	238.3	26.55	4684.9	95.16
Ash	475.2	6.67	258.0	28.74	217.2	

Table 307. (Continued)

Sheep G (Large roots)

	1 Weight eaten gm.	2 Analysis of feed per cent.	3 Weight of faeces gm.	4 Analysis of faeces per cent.	1 - 3	Digestibility Coefficient
DM	8438.5		875.4		7563.1	89.63
OM	7859.6	93.14	660.3	75.43	7199.3	91.60
CP	1012.6	12.00	264.4	30.02	748.2	73.89
EE	60.7	0.72	32.1	3.67	28.6	47.12
CF	898.7	10.65	135.2	15.44	763.5	84.96
NFE	5887.5	69.77	230.2	26.30	5657.3	96.09
Ash	578.9	6.86	215.1	24.57		

Sheep H (Large roots)

DM	6738.9		758.8		5980.1	88.74
OM	6276.6	93.14	568.2	74.88	5708.4	90.95
CP	808.7	12.00	195.2	25.73	613.5	75.86
EE	48.5	0.72	20.7	2.73	27.8	57.32
CF	717.6	10.65	146.6	19.32	571.0	79.57
NFE	4701.7	69.77	205.6	27.10	4496.1	95.63
Ash	462.3	6.86	190.6	25.12		

Table 307. (Continued)

Sheep H. Corrected for composition of residue.

	Weight fed gm.	Analysis of feed per cent.	Weight of residue gm.	Analysis of residue	Weight eaten gm.	Corrected Digestibility Coefficient
DM	7898.4		1159.5		6738.9	88.74
OM	7356.5	93.14	1047.6	90.35	6308.9	91.46
CP	995.1	12.60	167.8	14.48	827.3	78.16
EE	56.8	0.72	11.5	1.00	45.3	50.72
CF	841.1	10.65	156.1	13.47	685.0	75.02
NFE	5510.7	69.77	711.9	61.40	4738.8	96.41
Ash	541.8	6.86	111.8	9.65	430.0	51.78

Table 308. The percentage digestible nutrients in the dry matter, 1960.

Treatment	Small roots			Large roots	
Sheep	P	Q	R	T	U
OM	79.76	79.43	81.18	87.07	82.52
CP	2.90	3.08	2.86	6.15	4.66
EE	0.11	0.25	0.34	0.25	0.29
CF	7.31	7.71	8.47	9.31	8.71
NFE	69.44	68.39	69.96	71.36	68.85

Table 309 /

Table 309. The percentage digestible nutrients in the dry matter, 1961.

Treatment	Small roots			Large Roots	
Sheep	F	K	L	G	H
OM	84.01	85.69	84.35	85.32	85.18
CP	9.22	9.53	8.95	8.87	9.40
EE	0.35	0.25	0.28	0.34	0.36
CF	8.70	9.56	9.36	9.05	7.99
NFE	65.72	66.21	65.75	67.04	67.26

Table 310. The composition of the food residue of sheep H and K, and the uncorrected digestible nutrients for Sheep H.

	K	K	H	H	H
	Composition of the dry matter	Composition of the residue	Composition of the dry matter	Composition of the residue	Uncorrected digestible nutrients in the dry matter
	per cent.	per cent.	per cent.	per cent.	per cent.
OM	93.33	88.65	93.14	90.35	84.71
CP	12.25	18.28	12.00	14.48	9.10
EE	0.63	1.58	0.72	1.00	0.57
CF	11.35	16.94	10.65	13.47	7.96
NFE	69.10	51.85	69.77	61.40	66.72